MINERALS YEARBOOK

METALS AND MINERALS 1996

Volume I

U.S. GEOLOGICAL SURVEY

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY
Thomas Casadevall, *Acting Director*

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Foreword

This edition of the U.S. Geological Survey (USGS) Minerals Yearbook discusses the performance of the worldwide minerals and materials industries during 1996 and provides background information to assist in interpreting that performance. Content of the individual Minerals Yearbook volumes follows:

- Volume I, Metals and Minerals, contains chapters about virtually all metallic and industrial mineral commodities important to the U.S. economy. Chapters on survey methods, summary statistics for domestic nonfuel minerals, and trends in mining and quarrying in the metals and industrial minerals industries in the United States are also included.
- Volume II, Area Reports: Domestic, contains a chapter on the minerals industry of each of the 50 States and Puerto Rico and the Administered Islands. This volume also has chapters on survey methods and summary statistics for domestic nonfuel minerals.
- Volume III, Area Reports: International, is published as four separate reports. These regional reports contain the latest available minerals data on more than 190 foreign countries and discuss the importance of minerals to the economies of these nations and the United States. Each report begins with an overview of the region's mineral industries during the year. It continues with individual country chapters that examine the mining, refining, processing, and use of minerals in each country of the region and how each country's mineral industry relates to U.S. industry. Most chapters include production tables and industry structure tables, information about Government policies and programs that affect the country's mineral industry, and an outlook section.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the Minerals Yearbook are welcomed.

Thomas J. Casadevall
Acting Director

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Contacts

Information about the U.S. Geological Survey, its programs, staff, and products may be accessed on the World Wide Web at URL http://www.usgs.gov/. Aerial photography, digital data, geologic, and map products and information are available by contacting the Earth Science Information Center at 1-800-USA-MAPS. Water data and information may be obtained by contacting the Water Information Center at 1-800-426-9000. For specific information about this publication, contact Chief, Industrial Minerals Section, at (703) 648-4990; Chief, Metals Section, at (703) 648-4968; or Chief, Publication Services Section, Minerals Information Team, at (703) 648-4750. Information about the Minerals Information Team may be accessed on the World Wide Web at http://minerals.er.usgs.gov/minerals/ or via the MINES FaxBack at (703) 648-4999 from a touch-tone handset connected to the fax machine.

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Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook presents data on more than 80 minerals and materials that were obtained as a result of the information gathering activities of the U.S. Geological Survey.

The collection, compilation, and analysis of domestic mineral industry data were performed by the staff of the Minerals Information Team. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their responses are gratefully appreciated. Information obtained from individual firms by means of the U.S. Geological Survey canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted. The chapters on "Survey Methods" and "Statistical Summary" discuss in greater detail procedures for canvassing the mineral industry and the processing and evaluation of these data. Other information appearing in this volume was obtained from the trade and technical press, industry contacts, and additional sources; this cooperation is gratefully acknowledged.

Statistics on world production were compiled from numerous sources, including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the U.S. Department of Commerce, Bureau of the Census. The U.S. Geological Survey also was assisted by numerous cooperating State agencies.

John H. DeYoung, Jr.
Chief Scientist, Minerals Information Team

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SURVEY METHODS FOR NONFUEL MINERALS

By Kenneth W. Mlynarski

The U.S. Geological Survey (USGS) Minerals Information Team collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the base for tracking and assessing the health of the minerals sector of the U.S. economy.

The USGS data collection activity was instituted by the 47th Congress in an appropriations act of August 7, 1882 (22 Stat. 329), which placed the collection of mineral statistics on an annual basis. The most recent authority for the USGS survey activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479, 96th Congress). This act strengthens protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

Data Collection Surveys

The USGS begins the collection of domestic nonfuel minerals and materials statistics by appraising the information requirements of Government and private organizations of the United States. Requirements that can be met by collecting data from minerals establishments are posed as questions on USGS surveys. Figure 1 shows a typical survey form.

Specific questions about the production, consumption, shipment, and other activities of mineral commodities are structured in the survey forms to provide meaningful aggregated data. Thus, the entire mineral economic cycle from production through consumption is covered by 144 monthly, quarterly, semiannual, and annual surveys.

After the survey form has been designed, a list of the appropriate establishments to be canvassed is developed. Many sources are used to determine which companies, mines, plants, and other operations should be included on the survey mailing list. State geologists, Federal organizations (e.g., Mine Safety and Health Administration), trade associations, industry representatives, and trade publications and directories are some of the sources that are used to develop and update survey listings. With few exceptions, a complete canvass of the list of establishments is employed rather than a sample survey. The iron and steel scrap industry is one of the exceptions where a sample survey is conducted.

The Paperwork Reduction Act requires that any Government agency wanting to collect information from 10 or more individuals or establishments must first obtain approval from the Office of Management and Budget (OMB). OMB approves the need to collect the data and protects industry from unwarranted Government paperwork.

Survey Processing

The USGS surveys approximately 25,000 establishments. Each year, the USGS mails about 40,000 forms that gather information for 144 different surveys. Each completed survey form returned to the USGS undergoes extensive analysis to ensure the highest possible accuracy of the mineral data. The statistical staff monitors all surveys to ensure that errors are not created by reporting in physical units different from the units requested on the form. Relationships between related measures, such as produced crude ore and marketable crude ore, are analyzed for consistency. Engineering relationships, such as recovery factors from ores and concentrates, also are employed. The totals for each form are verified, and currently reported data are checked against prior reports to detect possible errors or omissions.

For the majority of the surveys, which are automated, the forms are reviewed to ensure that data are complete and correct before entering into the computer. The computer is programmed to conduct a series of automated checks to verify mathematical consistency and to identify discrepancies between the data reported and logically acceptable responses.

The USGS is modernizing and automating all of its survey processing and data dissemination functions. Automated commodity data system functions include computerized preparation of statistical tables, the use of desktop publishing to integrate text and tables, and electronic dissemination through the Internet. Also, information on minerals and mineral-related publications is now available through an easy-to-use automated fax response system known as MINES FaxBack.

Survey Responses.—To enable the reader to better understand the basis on which the statistics are calculated, each commodity annual report includes a section entitled "Domestic Data Coverage." This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production or consumption for nonrespondents.

To produce reliable aggregated data, the USGS employs efficient procedures for handling instances of nonresponse. Failure to return the initial survey form results in a second mailing of the form. If the second form is not returned, telephone calls are made to the nonrespondents. The followup calls provide the necessary data to complete the survey forms and/or verify questionable data entries. Periodic visits to minerals establishments also are made by

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USGS commodity specialists to gather missing data and to explain the importance of the establishment's reporting. By describing the use of the published statistics and showing the impact of nonresponse, the USGS strives to encourage respondents to give a complete and accurate reply.

The OMB "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate shall be 75% of the panel surveyed. In addition, the USGS strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics. Response rates are periodically reviewed. For those surveys not meeting the minimum reporting level, procedures are developed and implemented to improve response rates.

Estimation for Nonresponse.—When efforts to obtain a response to a survey fail, it becomes necessary to employ estimation or imputation techniques to account for missing data. These techniques are most effective when the response rate is relatively high. Some of the estimation methods depend on knowledge of prior establishment reporting, while other techniques rely on external information to estimate the missing data. When survey forms are received after the current publication has been completed, the forms are edited, necessary imputations are made for missing data, and the survey data base is updated. The revised data are reported in later publications.

Protection of Proprietary Data.—The USGS relies on the cooperation of the U.S. minerals industry to provide the mineral data that are presented in this and other USGS publications. Without a strong response to survey requests, the USGS would not be able to present reliable statistics. The USGS, in turn, respects the proprietary nature of the data received from the individual companies and establishments. To ensure that proprietary rights will not be violated, the USGS analyzes each of the aggregated statistics to determine if the data reported by an individual establishment can be deduced from the aggregated statistics. If, for example, there are only two significant producers of a commodity in a given State, the USGS will not publish the State total because either producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the "Withheld" or "W" entries in the published tables. However, if a company gives permission in writing, the USGS will publish the data as long as the data from other respondents are protected from disclosure.

International Data

International data are collected by country specialists and data assistants in the Minerals Information Team. The data are gathered from various sources, including published reports of foreign Government mineral and statistical agencies, international organizations, the U.S. Department of State, the United Nations, the Organization of Petroleum Exporting Countries, and personal contact by specialists traveling abroad. Each February, an annual "Minerals Questionnaire" is sent through the Department of State to more than 70 U.S. embassies asking them to provide estimates of mineral production for the host country for the preceding year. Missing data are estimated by USGS country specialists based on historical trends and on specialists' knowledge of current production capabilities in each country.

Publications

The USGS disseminates current and historical minerals information through a broad range of printed publications.

The Minerals Yearbook summarizes annually, on a calendar-year basis, the significant economic and technical developments in the mineral industries. Three separate volumes are issued each year: Volume I, Metals and Minerals; Volume II, Area Reports, Domestic; and Volume III, Area Reports, International. Chapters in Volume I are issued separately as Mineral Industry Surveys (MIS) before the bound volume is available. Volume I of the Minerals Yearbook presents, by mineral commodity, salient statistics on production, trade, consumption, reserves, and other measures of economic activity. Volume II of the Minerals Yearbook reviews the U.S. minerals industry by State and island possessions. Volume III of the Minerals Yearbook contains the latest available mineral data for the year of review on more than 185 foreign countries and discusses the importance of minerals to the economies of these nations.

The MIS contain timely statistical and economic data on minerals. The surveys are designed to keep Government agencies and the public, particularly the mineral industry and the business community, informed of trends in the production, distribution, inventories, and consumption of minerals. Frequency of issue depends on the demand for current data. The MIS are released monthly, quarterly, semiannually, and annually.

Mineral Commodity Summaries, an up-to-date summary of about 80 nonfuel mineral commodities, is the earliest Government publication to furnish estimates covering the previous year's nonfuel mineral industry data. It contains information on the domestic industry structure, Government programs, tariffs, 5-year salient statistics, and a summary of international mining news.

Metal Industry Indicators, published monthly, contains indexes that measure the current and future performance of four U.S. minerals industries. For each of the four industries, a composite coincident index and a composite leading index have been developed based on procedures and data similar to those used to construct the U.S. Department of Commerce's coincident and leading cyclical indicators for the national economy.

The MIS and the Metal Industry Indicators are available at no charge from Publication Distribution, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236, (412) 892-4338.

Minerals Yearbooks and Mineral Commodity Summaries may be purchased from the Superintendent of Documents,

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U.S. Government Printing Office, Washington, DC 20402, (202) 512-1800.

Mineral Commodity Summaries also may be purchased from the National Technical Information Service, Springfield, VA 22161, 1-800-553-NTIS (in Virginia and foreign countries: 1-703-487-4650).

Some Minerals Information publications are also available on a CD-ROM format. The CD-ROM is updated three times per year. It is available from the Government Printing Office at the address and phone number listed above.

Electronic Data Dissemination

In addition to the USGS's printed publications, current information on minerals and mineral-related publications from the USGS is now available through an easy-to-use automated fax response system. The MINES-FaxBack service allows callers to retrieve information and order some publications for delivery to their fax machines in minutes, 24 hours per day, 7 days per week. MINES-FaxBack makes monthly and quarterly MIS publications available to the public at the same time they are forwarded to the printer.

MINES-FaxBack works from any Group III-compatible fax machine equipped with a touch-tone telephone (either a built-in handset with touch-tone capability or a separate touch-tone telephone plugged into the fax machine's phone jack). After calling MINES FaxBack, the requestor is guided by a series of voice messages that assist the caller in ordering the desired documents. The caller pays for the phone call that also includes the time needed to deliver the requested document to the caller's fax machine.

To access the MINES-FaxBack System, use a touch-tone handset attached to a fax machine or connect a touch-tone telephone to the fax machine's telephone jack and dial (703) 648-4999. Listen to the menu options and select an option using the touch-tone telephone. After completing a selection, press the start button on the fax machine.

The Minerals Information Team also has a page on the World Wide Web detailing its publications, information products, and contacts. To access the page, use Netscape or a similar Web browser. The URL is http://minerals.er.usgs.gov/minerals/. The page also contains links to other mining-related pages on the Internet.

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FIGURE 1
A TYPICAL SURVEY FORM

Form 6-1153-A
Nonfer. (5-96)

C73

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
RESTON, VIRGINIA 20192

ROLLED ZINC

O.M.B.
Approval not required.

INDIVIDUAL COMPANY DATA—PROPRIETARY

Unless authorization is granted in the section above the signature, the data furnished in this report will be treated in confidence by the Department of the Interior, except that they may be disclosed to Federal defense agencies, or to the Congress upon official request for appropriate purposes.

FACSIMILE NUMBER
1-800-543-0661

(Please correct if name or address has changed.)

This form is designed to supplement form 6-1151-MA, Consumption of Slab Zinc, and is applicable to zinc rolling mills only. Please complete and return this form in the enclosed envelope to the U.S. Geological Survey.

This survey is exempt from the requirements of the Paperwork Reduction Act (44 U.S.C. 35) and does not require clearance by O.M.B. If you have any questions concerning this form, please contact the Supervisory Statistical Officer, Mineral Commodities Data Group, U.S. Geological Survey, Department of the Interior, Reston, VA 20192, (703) 648-7960.

1. Location of plant: City or town _____ State _____

2. Zinc consumed in manufacture of rolled zinc.

This is a measure of zinc entering the rolling mill for the first time. Do not include clippings originating from manufacturing finished products (coin blanks, battery cans, etc.) in your own fabricating plant.

Type of Zinc Consumed (1)	Code	Stocks at Plant at Beginning of Year (Gross weight) (Pounds) (2)	Receipts During Year (Gross weight) (Pounds) (3)	Melted or Consumed During Year (Gross weight) (Pounds) (4)	Stocks at Plant at End of Year (Gross weight) (Pounds) (5)
Zinc scrap	301				
Slab zinc	302				
Other (specify) _____	303				

3. Production and stocks of rolled zinc, by type.

Item (1)	Code	Stocks at Plant at Beginning of Year (Gross weight) (Pounds) (2)	(3)	Production During Year (Gross weight) (Pounds) (4)	Stocks at Plant at End of Year (Gross weight) (Pounds) (5)
Strip foil	402				
Rod and wire	405				
Coin alloy	406				
Other (specify) _____	407				
Total	408				

Name of person to be contacted regarding this report		Tel. area code	No.	Ext.
Address No. Street	City		State	Zip

May tabulations be published which could indirectly reveal the data reported above? ☐ (1) Yes ☐ (2) No

Signature	Title	Date

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STATISTICAL SUMMARY

By Stephen D. Smith

This report summarizes data on crude nonfuel mineral production for the United States, its island possessions, and the Commonwealth of Puerto Rico.

Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this annual report is what is termed "mine output." This term refers to minerals or ores in the form in which they are first extracted from the ground, but customarily may include the output from auxiliary processing at or near the mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. For copper, gold, lead, silver, tin, and zinc, the quantities shown are recorded on a mine basis (as the recoverable content of ore sold or treated). However, the values assigned to the quantities are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for the metal. Values shown are in current dollars, with no adjustments made to compensate for changes in the purchasing power of the dollar.

The total value of all nonfuel mineral production in the United States increased less than 1% to $38.7 billion in 1996, with metals decreasing almost 8% to $12.9 billion and industrial minerals rising almost 5% to $25.8 billion over that of 1995. Ten of the mineral commodities produced in the United States in 1996 had an individual total production value greater than $1 billion. These commodities, in descending order, were stone (crushed), cement (portland), copper, gold, sand and gravel (construction), iron ore, lime, clays (kaolin), phosphate rock, and salt. They composed almost 81% of the U.S. total production. (*See table 1.*)

In 1996, twelve States produced nonfuel mineral commodities with individual total production values of greater than $1 billion. These States, in descending order, were Arizona, Nevada, California, Florida, Georgia, Utah, Texas, Minnesota, Michigan, Missouri, Pennsylvania, and Wyoming. They composed almost 60% of the U.S. total production. (*See table 4.*)

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TABLE 1
NONFUEL MINERAL PRODUCTION 1/ IN THE UNITED STATES 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994		1995		1996	
		Quantity	Value	Quantity	Value	Quantity	Value
Metals:							
Antimony 3/	metric tons	215	W	262	W	242	W
Beryllium concentrates	do.	4,330	5	5,040	6	5,260	6
Copper 4/		1,810	4,430,000	1,850 r/	5,640,000	1,920	4,610,000
Gold 4/	kilograms	327,000	4,050,000	317,000 r/	3,950,000 r/	321,000	4,030,000
Iron ore, usable		57,600	1,410,000 r/	61,100	1,730,000 r/	62,200	1,770,000
Iron oxide pigments, crude	metric tons	46,400	6,010	51,700	6,720	44,700	6,990
Lead 4/	do.	363,000	298,000	386,000	359,000	426,000	459,000
Magnesium metal	do.	128,000	389,000	142,000	476,000	133,000	455,000
Molybdenum 3/	do.	46,000	284,000	W	W	57,900	456,000
Nickel ore 5/	do.	--	--	1,560	W	1,330	W
Palladium	kilograms	6,440	29,400	5,260	22,000	6,100	25,500
Platinum	do.	1,960	25,300	1,590	20,800	1,840	23,500
Rare-earth metal concentrates	metric tons	W	W	22,200	W	20,400	W
Silver 4/	do.	1,490	253,000	1,560 r/	259,000 r/	1,570	263,000
Zinc 4/	do.	570,000	619,000	614,000	756,000	600,000	676,000
Combined value of bauxite, manganiferous ore, mercury, titanium concentrates, tungsten, vanadium, zircon concentrates and values indicated by symbol W		XX	147,000	XX	812,000 r/	XX	190,000
Total metals		XX	11,900,000 r/	XX	14,000,000 r/	XX	13,000,000
Industrial minerals, excluding fuels:							
Asbestos	metric tons	10,100	5,120	10,200	W	9,550	W
Barite		583	19,100	543	10,400 r/	662	14,700
Boron minerals, B_2O_3	metric tons	1,110,000	443,000	1,190,000 r/	560,000 r/	1,150,000	519,000
Bromine	do.	195,000	155,000	218,000	186,000	227,000	150,000
Cement:							
Masonry		3,610	286,000	3,600	307,000	3,470	321,000 e/
Portland		74,300	4,460,000	73,300	4,920,000	75,800	5,310,000 e/
Clays:							
Ball		1,050	45,600	993	45,500	973	43,100
Bentonite		3,290	136,000	3,820	138,000	3,740	134,000
Common		25,900	142,000	25,600	151,000	26,200	144,000
Fire		458	11,700	583	12,800	505	10,700
Fuller's earth		2,640	244,000	2,640	269,000	2,600	278,000
Kaolin		8,770	1,020,000	9,480	1,110,000	9,120	1,100,000
Diatomite		613	152,000	687	171,000	698	176,000
Feldspar	metric tons	765,000	31,200	882,000	37,400	890,000	39,400
Fluorspar	do.	49,000	W	51,400	W	8,180	W
Garnet, industrial	do.	51,000	6,100	53,000	9,690 r/	68,200	10,200
Gemstones		NA	50,500	NA	48,700 r/	NA	43,600
Gypsum, crude		17,200	115,000	16,600	121,000	17,500	124,000
Helium:							
Crude	million cubic meters	39	38,500	36	32,100	37	33,100
Grade-A	do.	100	199,000	99	196,000	97	193,000
Iodine	metric tons	1,630	12,800	1,220	12,500	1,270	14,600
Lime		17,400	1,020,000	18,500	1,100,000	19,100	1,140,000
Mica, crude		110	5,780	108	5,630	97	7,820
Peat		552	15,300	660 6/	17,000 6/	640 6/	18,500 6/
Perlite, crude	metric tons	644,000	19,400	700,000	21,600	684,000	21,300
Phosphate rock		41,100	869,000	43,500	947,000	45,400	1,060,000
Potash, K_2O		2,970	284,000	2,880	284,000	2,960	299,000
Pumice and pumicite	metric tons	490,000	11,800	529,000	13,200	612,000	14,800
Salt		39,700	990,000	40,800	1,000,000	42,900	1,060,000
Sand and gravel:							
Construction		891,000	3,740,000	910,000	3,910,000	914,000	4,000,000
Industrial		27,300	488,000	28,200	502,000	27,800	497,000
Silica stone 7/	metric tons	487 r/	W	374	W	410	3,810
Sodium compounds:							
Soda ash		9,320	724,000	10,100	829,000	10,200	926,000
Sodium sulfate, natural		298	24,200	327	27,700	306	27,200
Stone, crushed 8/		1,230,000	6,620,000	1,260,000	6,750,000	1,330,000	7,180,000
Sulfur, Frasch		3,010	162,000	3,070	207,000	W	W
Tripoli	metric tons	82,300	10,900	80,100	10,500	79,600	18,400

See footnotes at end of table.

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TABLE 1--Continued
NONFUEL MINERAL PRODUCTION 1/ IN THE UNITED STATES 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Industrial minerals, excluding fuels--Continued:							
Vermiculite	metric tons	177,000	14,200	171,000	W	W	W
Zeolites	do.	57,600 r/	NA	46,800	NA	39,300	NA
Combined value of brucite, emery, greensand marl, kyanite, lithium minerals, magnesite, magnesium compounds, olivine, staurolite, stone (dimension), talc and pyrophyllite, wollastonite and values indicated by symbol W		XX	535,000 r/	XX	626,000 r/	XX	818,000
Total industrial minerals		XX	23,100,000	XX	24,600,000 r/	XX	25,800,000
Grand total		XX	35,000,000 r/	XX	38,600,000 r/	XX	38,700,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value." XX Not applicable.

1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Content of ore and concentrate.

4/ Recoverable content of ores, etc.

5/ Quantity of local ore fed to smelter after rejection of lower grade material. The smelter uses lateritic ore imported from New Caledonia in addition to lateritic ore mined on Nickel Mountain. In 1995, the smelter was idle from January to the beginning of May because of low nickel prices.

6/ Data series changed to production beginning in 1995; prior years shipment data may not be comparable.

7/ Includes grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

8/ Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.

TABLE 2
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 1996

(Based on quantity unless otherwise noted)

Mineral	Principal States	Other States
Antimony 1/	ID	
Asbestos	CA	
Barite	NV, GA, MO, TN	
Beryllium concentrate	UT	
Boron, B_2O_3	CA	
Bromine	AR and MI	
Brucite	NV	
Cement:		
Masonry	FL, IN, AL, SC, PA	AZ, AR, CA, CO, GA, HI, ID, IA, KS, KY, ME, MD, MI, MO, MT, NE, NY, OH, OK, SD, TN, TX, UT, VA, WA, WV.
Portland	CA, TX, PA, MI, MO	All other States, except AK, CT, DE, LA, MA, MN, NH, NJ, NC, ND, RI, VT, WI.
Clays:		
Ball	TN, TX, MS, KY, IN	MO.
Bentonite	WY, AL, MT, CA, MS	AZ, CO, NV, OR, UT.
Common	NC, AL, TX, OH, GA	All other States, except AK, DE, HI, ID, NV, RI, VT, WI.
Fire	MO, OH, CA, AL, SC	AR, MT, NM, OK.
Fuller's earth	GA, MS, FL, IL, MO	CA, KS, NV, TN, TX, UT, VA.
Kaolin	GA, SC, AL, AR, CA	CO, FL, NV, NC, PA, TN, TX.
Copper 1/	AZ, UT, NM, MT, NV	AK, ID, IL, MO, TN, WI.
Diatomite	CA, NV, OR, WA	
Emery	OR	
Feldspar	NC, CA, VA, GA, OK	ID and SD.
Fluorspar	IL	
Garnet, abrasive	NY, ID, MT	
Gemstones, natural 2/	TN, OR, KY, AR, AZ	All other States.
Gold 1/	NV, CA, UT, SD, MT	AK, AZ, CO, ID, NM, SC, WA, WI.
Greensand marl	NJ	
Gypsum, crude	OK, TX, IA, MI, NV	AZ, AR, CA, CO, IN, KS, LA, NM, NY, OH, SD, UT, VA, WA, WY.
Helium:		
Crude	KS, TX, OK	
Grade-A	KS, WY, TX, UT, CO	OK.
Iodine	OK	
Iron ore, usable	MN, MI, MO, NM, SD	CA.
Iron oxide pigments, crude	MI, MO, GA, VA, AZ	
Kyanite	VA	

See footnotes at end of table.

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TABLE 2--Continued
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 1996

(Based on quantity unless otherwise noted)

Mineral	Principal States	Other States
Lead 1/	MO, AK, ID, MT, CO	IL, NY, TN.
Lime	MO, OH, KY, AL, PA	All other States, except AK, CT, DE, FL, GA, HI, KS, ME, MD, MS, NH, NJ, NM, NY, NC, RI, SC, VT.
Lithium minerals	NC and NV	
Magnesite	NV	
Magnesium compounds	MI, CA, UT, FL, DE	TX.
Magnesium metal	TX, UT, WA	
Mercury	NV, CA, UT	
Mica, crude	NC, NM, SD, SC, GA	
Molybdenum	AZ, CO, UT, ID, MT	NM.
Nickel ore	OR	
Olivine	NC and WA	
Palladium metal	MT	
Peat	FL, MI, IL, IN, MN	CO, IA, ME, MA, MT, NJ, NY, NC, ND, OH, PA, WA, WV, WI.
Perlite	NM, AZ, CA, NV	
Phosphate rock	FL, ID, NC, UT	
Platinum metal	MT	
Potash, K_2O	NM, UT, CA, MI	
Pumice and pumicite	OR, ID, NM, CA, AZ	KS.
Rare-earth metal concentrates	CA	
Salt	LA, TX, OH, NY, KS	AL, AZ, CA, MI, NV, NM, OK, UT, WV.
Sand and gravel:		
Construction	CA, TX, MI, OH, AZ	All other States, except HI.
Industrial	IL, MI, CA, NJ, WI	All other States, except AK, CT, DE, HI, KY, ME, NH, NM, OR, SD, UT, VT, WY.
Silica stone 3/	AR, WI, OH	
Silver 1/	NV, ID, AK, AZ, UT	CA, CO, IL, MO, MT, NM, NY, SC, SD, TN, WI.
Sodium compounds:		
Soda ash	WY and CA	
Sodium sulfate, natural	CA and TX	
Staurolite	FL	
Stone:		
Crushed	PA, TX, FL, MO, IL	All other States, except DE and ND.
Dimension	IN, WI, VT, GA, TX	All other States except AK, DE, FL, HI, IL, IA, KY, LA, MS, NE, NV, NJ, ND, OR, RI, WY.
Sulfur, Frasch	LA and TX	
Talc and pyrophyllite	MT, TX, VT, NY, NC	CA, OR, VA.
Titanium concentrates:		
Ilmenite	FL and CA	
Rutile	FL	
Tripoli	IL, OK, AR, PA	
Vanadium 1/	ID	
Vermiculite, crude	SC and VA	
Wollastonite	NY	
Zeolites	NM, TX, OR, AZ, NV	WY.
Zinc 1/	AK, TN, NY, MO, MT	CO, ID, IL.
Zircon concentrates	FL	

1/ Content of ores, etc.

2/ Principal producing States based on value.

3/ Includes grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

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TABLE 3

VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 1996 1/

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Alabama	$778,000	17	2.01	Cement (portland), stone (crushed), lime, sand and gravel (construction), and cement (masonry).
Alaska	613,000	21	1.58	Zinc, lead, gold, silver, and sand and gravel (construction).
Arizona	3,580,000	1	9.26	Copper, sand and gravel (construction), cement (portland), molybdenum, and lime.
Arkansas	435,000	31	1.12	Stone (crushed), bromine, cement (portland), sand and gravel (construction), and sand and gravel (industrial).
California	2,830,000	3	7.31	Cement (portland), sand and gravel (construction), boron minerals, gold, and stone (crushed).
Colorado	513,000	25	1.33	Sand and gravel (construction), cement (portland), gold, molybdenum, and stone (crushed).
Connecticut 2/	81,900	44	0.21	Stone (crushed), sand and gravel (construction), stone (dimension), clays (common), and gemstones (natural).
Delaware 2/	6,820	50	0.02	Magnesium compounds, sand and gravel (construction), and gemstone (natural).
Florida	1,760,000	4	4.56	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction), and clays (fuller's earth).
Georgia	1,740,000	5	4.50	Clays (kaolin), stone (crushed), cement (portland), clays (fuller's earth), and sand and gravel (construction).
Hawaii 2/	110,000	43	0.28	Stone (crushed), cement (portland), cement (masonry), and gemstones (natural).
Idaho	492,000	27	1.27	Phosphate rock, gold, molybdenum, sand and gravel (construction), and silver.
Illinois	846,000	16	2.19	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial), and lime.
Indiana	628,000	20	1.62	Stone (crushed), cement (portland), sand and gravel (construction), lime, and cement (masonry).
Iowa	470,000	29	1.21	Stone (crushed), cement (portland), sand and gravel (construction), gypsum (crude), and lime.
Kansas	530,000	24	1.37	Cement (portland), salt, stone (crushed), helium (Grade-A), sand and gravel (construction).
Kentucky	442,000	30	1.14	Stone (crushed), lime, cement (portland), sand and gravel (construction), and gemstone (natural).
Louisiana	393,000	33	1.01	Salt, sulfur (Frasch), sand and gravel (construction), stone (crushed), and sand and gravel (industrial).
Maine	68,600	45	0.18	Sand and gravel (construction), cement (portland), stone (crushed), peat, and cement (masonry).
Maryland	332,000	36	0.86	Stone (crushed), cement (portland), sand and gravel (construction), and stone (dimension), and cement (masonry).
Massachusetts	200,000	39	0.52	Stone (crushed), sand and gravel (construction), stone (dimension), lime, and clays (common).
Michigan	1,540,000	9	3.97	Iron ore (usable), cement (portland), sand and gravel (construction), magnesium compounds, and stone (crushed).
Minnesota	1,540,000	8	3.99	Iron ore (usable), sand and gravel (construction), stone (crushed), sand and gravel (industrial), and stone (dimension).
Mississippi	144,000	42	0.37	Sand and gravel (construction), cement (portland), clays (fuller's earth), stone (crushed), and clays (ball).
Missouri	1,250,000	10	3.23	Lead, stone (crushed), cement (portland), lime, and zinc.
Montana	491,000	28	1.27	Gold, copper, cement (portland), molybdenum, and sand and gravel (construction).
Nebraska	148,000	41	0.38	Cement (portland), sand and gravel (construction), stone (crushed), clays (common), and cement (masonry).
Nevada	3,230,000	2	8.34	Gold, sand and gravel (construction), copper, silver, and diatomite.
New Hampshire 2/	51,700	47	0.13	Sand and gravel (construction), stone (crushed), stone (dimension), clays (common), and gemstones (natural).
New Jersey 2/	246,000	38	0.64	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), greensand marl, and peat.
New Mexico	992,000	13	2.56	Copper, potash, sand and gravel (construction), cement (portland), and stone (crushed).
New York	891,000	15	2.30	Stone (crushed), salt, cement (portland), sand and gravel (construction), and zinc.
North Carolina	690,000	18	1.78	Stone (crushed), phosphate rock, lithium minerals, sand and gravel (construction), and sand and gravel (industrial).
North Dakota	30,800	48	0.08	Sand and gravel (construction), lime, clays (common), sand and gravel (industrial), and gemstones (natural).
Ohio	969,000	14	2.50	Stone (crushed), salt, sand and gravel (construction), lime, and cement (portland).
Oklahoma	369,000	34	0.95	Cement (portland), stone (crushed), sand and gravel (construction), sand and gravel (industrial), and gypsum (crude).
Oregon	265,000	37	0.68	Stone (crushed), sand and gravel (construction), cement (portland), diatomite, and lime.
Pennsylvania 2/	1,170,000	11	3.02	Stone (crushed), cement (portland), lime, sand and gravel (construction), and cement (masonry).
Rhode Island 2/	23,000	49	0.06	Sand and gravel (constructioin), stone (crushed), sand and gravel (industrial), and gemstone (natural).
South Carolina	493,000	26	1.27	Cement (portland), stone (crushed), gold, sand and gravel (construction), and cement (masonry).
South Dakota	357,000	35	0.92	Gold, cement (portland), stone (crushed), sand and gravel (construction), and lime.
Tennessee	662,000	19	1.71	Stone (crushed), zinc, cement (portland), sand and gravel (construction), and clays (ball).
Texas	1,730,000	7	4.47	Cement (portland), stone (crushed), sand and gravel (construction), magnesium metal, and salt.
Utah	1,730,000	6	4.48	Copper, gold, molybdenum, magnesium metal, and sand and gravel (construction).
Vermont 2/	66,000	46	0.17	Stone (dimension), stone (crushed), sand and gravel (construction), talc and pyrophyllite, and gemstones (natural).
Virginia	549,000	22	1.42	Stone (crushed), cement (portland), sand and gravel (construction), lime, and kyanite.
Washington	535,000	23	1.38	Sand and gravel (construction), magnesium metal, stone (crushed), cement (portland), and gold.
West Virginia	185,000	40	0.48	Stone (crushed), cement (portland), sand and gravel (industrial), lime, and salt.
Wisconsin	396,000	32	1.02	Stone (crushed), sand and gravel (construction), copper, sand and gravel (industrial), and lime.
Wyoming	1,080,000	12	2.79	Soda ash, clays (bentonite), helium (Grade-A), cement (portland), and stone (crushed).
Undistributed	30,200	XX	0.08	
Total	38,700,000	XX	100.00	

XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Partial total; excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed."

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TABLE 4
VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE KILOMETER IN 1996, BY STATE 1/

State	Area (square kilometers)	Population (thousands)	Total value (thousands)	Per capita		Per square kilometer	
				Dollars	Rank	Dollars	Rank
Alabama	134,000	4,250	$778,000	183	14	5,810	22
Alaska	1,530,000	604	613,000	1,020	3	400	49
Arizona	295,000	4,220	3,580,000	850	5	12,100	3
Arkansas	138,000	2,480	435,000	175	15	3,160	30
California	411,000	31,600	2,830,000	90	34	6,880	16
Colorado	270,000	3,750	513,000	137	18	1,900	41
Connecticut	13,000	3,270	81,900 2/	25	48	6,300	19
Delaware	5,290	717	6,820 2/	10	50	1,290	44
Florida	152,000	14,200	1,760,000	125	21	11,600	4
Georgia	153,000	7,200	1,740,000	242	11	11,400	5
Hawaii	16,800	1,190	110,000 2/	93	30	6,570	18
Idaho	216,000	1,160	492,000	423	9	2,270	38
Illinois	146,000	11,800	846,000	72	39	5,800	23
Indiana	93,700	5,800	628,000	108	25	6,710	17
Iowa	146,000	2,840	470,000	165	16	3,220	28
Kansas	213,000	2,570	530,000	207	13	2,490	37
Kentucky	105,000	3,860	442,000	114	22	4,220	27
Louisiana	124,000	4,340	393,000	90	32	3,170	29
Maine	86,200	1,240	68,600	55	41	796	47
Maryland	27,100	5,040	332,000	66	40	12,300	1
Massachusetts	21,500	6,070	200,000	33	46	9,330	9
Michigan	152,000	9,550	1,540,000	161	17	10,100	7
Minnesota	219,000	4,610	1,540,000	335	10	7,060	13
Mississippi	124,000	2,700	144,000	53	42	1,170	45
Missouri	181,000	5,320	1,250,000	235	12	6,920	15
Montana	381,000	870	491,000	564	7	1,290	43
Nebraska	200,000	1,640	148,000	90	33	738	48
Nevada	286,000	1,530	3,230,000	2,110	2	11,300	6
New Hampshire	24,000	1,150	51,700 2/	45	45	2,150	39
New Jersey	20,200	7,950	246,000 2/	31	47	12,200	2
New Mexico	315,000	1,690	992,000	589	6	3,150	31
New York	127,000	18,100	891,000	49	43	7,010	14
North Carolina	136,000	7,200	690,000	96	29	5,050	25
North Dakota	183,000	641	30,800	48	44	168	50
Ohio	107,000	11,200	969,000	87	35	9,050	10
Oklahoma	181,000	3,280	369,000	113	24	2,040	40
Oregon	251,000	3,140	265,000	84	36	1,050	46
Pennsylvania	117,000	12,100	1,170,000 2/	97	28	9,960	8
Rhode Island	3,140	990	23,000 2/	23	49	7,310	12
South Carolina	80,600	3,670	493,000	134	19	6,120	20
South Dakota	200,000	729	357,000	490	8	1,790	42
Tennessee	109,000	5,260	662,000	126	20	6,070	21
Texas	691,000	18,700	1,730,000	92	31	2,500	36
Utah	220,000	1,950	1,730,000	889	4	7,890	11
Vermont	24,900	585	66,000 2/	113	23	2,650	35
Virginia	106,000	6,620	549,000	83	37	5,200	24
Washington	176,000	5,430	535,000	99	27	3,030	32
West Virginia	62,800	1,830	185,000	101	26	2,950	33
Wisconsin	145,000	5,120	396,000	77	38	2,720	34
Wyoming	253,000	480	1,080,000	2,250	1	4,260	26
Undistributed	XX	XX	30,200	XX	XX	XX	XX
Total or average	9,370,000 3/	262,000 3/	38,700,000	148	XX	4,130	XX

XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Partial total; excludes values that must be concealed to avoid disclosing company proprietary data. Concealed values included with "Undistributed."

3/ Excludes Washington, DC (which has no mineral production), with an area of 179 square kilometers and a population of 554,000.

Sources: U.S. Geological Survey and Bureau of the Census.

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TABLE 5
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Alabama:							
Cement:							
Masonry		312	28,900	306	30,700	309	32,000 e/
Portland		3,980	248,000	4,090	285,000	4,330	326,000 e/
Clays:							
Bentonite		W	W	154	4,700	166	5,060
Common		2,010	18,900	2,080	18,600	2,290	17,100
Fire		72	3,190	80	3,120	52	2,800
Kaolin		199	3,270	373	7,220	254	W
Gemstones		NA	W	NA	3,000 r/	NA	2,000
Lime		1,660	88,300	1,730	105,000	1,860	116,000
Sand and gravel:							
Construction		12,500	47,600	11,900	49,400	13,800	60,600
Industrial		610	7,160	479	5,940	799	8,380
Stone: Crushed		32,500	164,000	33,600	174,000	38,900	198,000
Combined value of bauxite (1994-95), salt, stone [dimension limestone, marble, and sandstone (1994), dimension limestone and sandstone (1995-96)], and values indicated by symbol W		XX	16,500	XX	6,810	XX	9,930
Total		XX	626,000	XX	693,000 r/	XX	778,000
Alaska:							
Gemstones		NA	10	NA	10	NA	11
Gold 3/ 4/	kilograms	5,660	70,300	4,410	56,000	5,020	61,000
Sand and gravel: Construction		15,700	56,200	13,700	48,500	9,380	35,900
Silver 3/	metric tons	W	W	109	18,100	W	W
Stone: Crushed		3,870	24,100	3,320 5/	20,400 5/	2,600 5/	16,500 5/
Zinc 3/	metric tons	W	W	321,000	395,000	W	W
Combined values of copper (1996), lead, stone [crushed dolomite and limestone (1995-96)], and values indicated by symbol W		XX	367,000	XX	(6/)	XX	499,000
Total		XX	518,000	XX	538,000 7/	XX	613,000
Arizona:							
Clays:							
Bentonite		W	W	21	W	W	W
Common		98	452	98	449	104	W
Copper 3/		1,120	2,750,000	1,170	3,560,000	1,240	2,980,000
Gemstones		NA	3,550	NA	3,230	NA	2,360
Gold 3/	kilograms	2,050	25,300	1,920	23,900	1,740	21,800
Iron oxide pigments, crude	metric tons	77	62	68	90	W	W
Sand and gravel:							
Construction		34,800	166,000	40,100	201,000	41,900	199,000
Industrial		W	W	334	2,910	323	2,890
Silver 3/	metric tons	198	33,700	220	36,400	188	31,300
Stone: Crushed		4,970	25,000	5,520	32,600	6,800	40,600
Combined value of cement, gypsum (crude), lime, molybdenum, perlite (crude), pumice and pumicite, salt, stone (dimension sandstone), and values indicated by symbol W		XX	274,000	XX	331,000	XX	308,000
Total		XX	3 280,000	XX	4,190,000	XX	3 580,000
Arkansas:							
Clays:							
Common		883	2,440	973	2,920	939	2,390
Kaolin		W	W	182	4,890	161	W
Gemstones		NA	3,950	NA	4,890	NA	3,050
Sand and gravel:							
Construction		10,600	42,500	11,600	48,300	11,000	43,500
Industrial		684	8,230	W	W	W	W
Silica stone 8/	metric tons	442 r/	W	W	W	398	3,800
Stone:							
Crushed		20,800 5/	122,000 5/	25,500	169,000	26,400	158,000
Dimension	metric tons	W	W	22,000	2,010	W	W

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Arkansas--Continued:							
Combined value of bromine, cement, clays (fire), gypsum (crude), limestone [crushed limestone and traprock (1994), dimension limestone, marble, and sandstone (1994, 1996)], tripoli, and values indicated by symbol W		XX	258,000 r/	XX	260,000	XX	225,000
Total		XX	463,000 r/	XX	492,000	XX	435,000
California:							
Asbestos	metric tons	8,990	4,200	10,200	W	9,550	W
Boron minerals (B_2O_3)		550	443,000	1,190 r/	560,000 r/	1,150	519,000
Cement:							
Masonry		99	6,830	154	11,200	198	14,500 e/
Portland		9,640	539,000	9,360	565,000	9,910	616,000 e/
Clays:							
Bentonite		144	13,700	149	14,000	148	13,900
Common		1,420	6,910	1,420	14,500	1,340	12,600
Fire		--	--	11	311	60	W
Fuller's earth		W	W	224	W	224	W
Diatomite		W	W	318	W	W	W
Gemstones		NA	1,710	NA	490	NA	507
Gold 3/	kilograms	30,100	373,000	25,600 r/	319,000 r/	23,800	299,000
Lime		203	16,900	228	15,600	208	17,800
Rare-earth metal concentrates	metric tons	20,700	W	22,200	W	20,400	W
Sand and gravel:							
Construction		96,300	523,000	98,400	542,000	103,000	583,000
Industrial		1,740	39,400	1,710	38,300	1,760	40,500
Silver 3/	metric tons	11	1,910	14 r/	2,240 r/	22	3,610
Stone:							
Crushed		41,100	258,000	43,700 5/	268,000 5/	46,700	295,000
Dimension	metric tons	11,100 5/	4,030 5/	27,300	6,660	28,600	7,020
Combined value of feldspar, gypsum (crude), iron ore (usable), magnesium compounds, mercury, perlite (crude), potash, pumice and pumicite, salt, soda ash, sodium sulfate (natural), stone [crushed dolomite and shell (1995), dimension limestone, sandstone, slate and miscellaneous (1994)], talc and pyrophyllite, titanium concentrates [ilmenite (1994, 1996)], tungsten, and values indicated by symbol W		XX	364,000	XX	399,000	XX	408,000
Total		XX	2,590,000	XX	2,760,000 r/	XX	2,830,000
Colorado:							
Clays:							
Bentonite		1	12	(9/)	9	1	19
Common		288	2,180	288	2,040	317	2,320
Fire		(9/)	7	--	--	--	--
Kaolin		2	120	6	W	6	W
Gemstones		NA	267	NA	245	NA	754
Gold 3/	kilograms	4,420	54,700	W	W	W	W
Sand and gravel: Construction		29,000	109,000	34,100	141,000	31,600	133,000
Silver 3/	metric tons	W	W	W	W	7	1,240
Stone:							
Crushed		8,260 5/	52,300 5/	9,000	58,500	9,940	64,900
Dimension	metric tons	3,630 5/	51 5/	17,800	2,640	23,900	3,330
Combined value of cement, gypsum (crude), helium (Grade-A), lead, lime, molybdenum, peat, sand and gravel (industrial), stone [crushed traprock and volcanic cinder (1994), dimension marble (1994)], zinc, and values indicated by symbol W		XX	192,000	XX	366,000	XX	308,000
Total		XX	410,000	XX	570,000	XX	513,000
Connecticut:							
Gemstones		NA	5	NA	5	NA	5
Sand and gravel: Construction		5,420	28,000	6,410	37,500	6,380	26,900

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Connecticut--Continued:							
Stone: Crushed		5,710	43,900 5/	6,070 5/	45,500 5/	6,720	55,000
Combined value of other industrial minerals		XX	9,810	XX	9,470	XX	(6/)
Total		XX	81,800	XX	92,500	XX	81,900 7/
Delaware:							
Gemstones		NA	1	NA	1	NA	1
Sand and gravel: Construction		2,580	8,680	2,680	8,740	2,370	6,820
Total 7/		XX	8,680	XX	8,750	XX	6,820
Florida:							
Cement:							
Masonry		400	34,600	383	35,200	422	35,200 e/
Portland		3,370	228,000	3,170	233,000	3,450	245,000 e/
Clays:							
Fuller's earth		395	51,500	388	50,800	377	58,900
Kaolin		35	3,450	33	3,510	35	3,760
Gemstones		NA	W	NA	W	NA	1
Peat		206	3,230	294 10/	5,390 10/	298 10/	5,550 10/
Sand and gravel:							
Construction		16,600	60,700	19,300	69,300	18,500	68,800
Industrial		540	6,120	547	6,340	515	6,340
Stone: Crushed		66,300 5/	343,000	68,000	350,000	73,600 5/	394,000 5/
Combined value of clays (common), magnesium compounds, phosphate rock, rare-earth metal concentrates (1994), staurolite, stone [crushed marl (1994, 1996)], titanium concentrates (ilmenite and rutile), zirconium concentrates, and values indicated by symbol W		XX	669,000	XX	783,000	XX	947,000
Total		XX	1,400,000	XX	1,540,000	XX	1,760,000
Georgia:							
Clays:							
Common		1,710	11,200	1,660	11,200	1,660	11,200
Fuller's earth		680	83,700	744	90,100	739	89,200
Kaolin		7,570	962,000	8,240	1,060,000	8,040	1,050,000
Gemstones		NA	51	NA	51	NA	32
Sand and gravel:							
Construction		5,520	19,800	5,780	23,100	6,520	24,500
Industrial		440	7,040	574	7,060	313	5,650
Stone:							
Crushed		54,600	331,000	60,600	373,000	63,400 5/	401,000 5/
Dimension	metric tons	200,000 5/	19,100 5/	132,000	27,700	89,600 5/	10,300 5/
Combined value of barite, bauxite (1994-95), cement, clays [fire (1994)], feldspar, iron oxide pigments (crude), mica (crude), and stone [crushed marble (1996), dimension marble (1996), dimension marble and miscellaneous (1994)]		XX	115,000	XX	102,000 r/	XX	148,000
Total		XX	1,550,000	XX	1,690,000 r/	XX	1,740,000
Hawaii:							
Cement:							
Masonry		6	395	5	501	5	500 e/
Portland		404	28,300	357	35,500	312	32,000 e/
Gemstones		NA	(6/)	NA	(6/)	NA	153
Sand and gravel: Construction		521	4,740	405	4,030	W	(6/)
Stone: Crushed		8,170	82,300	7,450 5/	73,500 5/	6,560	77,500
Total 7/		XX	116,000	XX	114,000	XX	110,000
Idaho:							
Antimony	metric tons	215	W	262	W	242	W
Clays: Common		--	--	1	10	--	--
Gemstones		NA	287	NA	346	NA	347
Gold 3/	kilograms	W	W	8,850	110,000	10,800 r/	135,000 r/
Pumice and pumicite	metric tons	W	W	W	W	159,000	1,340
Sand and gravel:							
Construction		14,500	46,300	13,200	43,500	14,700	46,100

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Idaho--Continued:							
Sand and gravel--Continued:							
Industrial		W	W	501	8,720	646	8,510
Silver 3/	metric tons	W	W	182	30,200	229	38,300
Stone: Crushed		4,160	20,300	3,210 5/	14,000 5/	3,960 5/	20,200 5/
Combined value of cement, copper, feldspar, garnet (industrial), lead, lime, molybdenum, phosphate rock, stone [crushed miscellaneous (1995-96), dimension marble and miscellaneous (1994), dimension quartzite (1995), dimension quartzite and miscellaneous (1996)], vanadium ore, zinc, and values indicated by symbol W		XX	273,000	XX	303,000	XX	242,000
Total		XX	340,000	XX	510,000	XX	492,000 r/
Illinois:							
Cement: Portland		2,590	151,000	2,560	169,000	2,620	181,000 e/
Clays:							
Common		494	1,170	503	1,220	115	736
Fuller's earth		W	W	332	W	330	W
Fluorspar	metric tons	49,000	W	51,400	W	8,180	W
Gemstones		NA	376	NA	269	NA	890
Sand and gravel:							
Construction		37,900	150,000	36,100	147,000	34,600	144,000
Industrial		4,420	65,700	4,410	67,500	4,460	66,400
Stone: Crushed		62,600 5/	353,000 5/	61,400	335,000	66,500	364,000
Combined value of barite (1994-95), cement [masonry (1994)], copper, lead, lime, peat, silver, stone [crushed miscellaneous (1994), dimension dolomite (1994)], tripoli, zinc, and values indicated by symbol W		XX	102,000	XX	107,000	XX	89,100
Total		XX	823,000	XX	828,000	XX	846,000
Indiana:							
Cement: Portland		2,290	132,000	2,330	143,000	2,350	153,000 e/
Clays:							
Ball		W	W	38	W	38	W
Common		774	2,540	877	3,350	1,510	3,500
Gemstones		NA	29	NA	36	NA	3
Peat		23	W	17 10/	281 10/	W	W
Sand and gravel: Construction		28,100	108,000	24,900	93,900	24,800	100,000
Stone:							
Crushed		45,900	211,000	49,200	234,000 5/	53,700 5/	254,000 5/
Dimension	metric tons	173,000	25,800	172,000	31,400	156,000 5/	24,500 5/
Combined value of cement (masonry), gypsum (crude), lime, sand and gravel (industrial), stone [crushed slate (1995-96), dimension dolomite (1996)], and values indicated by symbol W		XX	75,400	XX	82,700	XX	92,800
Total		XX	555,000	XX	589,000	XX	628,000
Iowa:							
Cement: Portland		2,390	153,000	2,340	161,000	2,390	187,000 e/
Clays: Common		384	1,520	322	1,590	478	1,180
Gemstones		NA	50	NA	57	NA	481
Gypsum, crude		2,210	12,700	2,240	13,800	2,090	12,800
Peat		5 r/	W	5 10/	77 10/	W	W
Sand and gravel: Construction		15,300	58,200	14,300	57,000	13,300	54,600
Stone: Crushed		36,600 5/	211,000	35,300	210,000	34,400	202,000
Combined value of cement (masonry), lime, sand and gravel (industrial), stone [dimension (1994), dimension dolomite and sandstone (1995)], and values indicated by symbol W		XX	14,800	XX	12,500	XX	11,100
Total		XX	451,000	XX	456,000	XX	470,000
Kansas:							
Cement:							
Masonry		24	2,090	31	2,650	24	2,240 e/

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Kansas--Continued:							
Cement--Continued:							
Portland		1,640	101,000	1,730	109,000	1,730	120,000 e/
Clays							
Common		556	2,150	573	2,390	548	2,250
Fuller's earth		W	W	48	W	64	W
Gemstones		NA	W	NA	W	NA	621
Helium:							
Crude	million cubic meters	32	31,400	30	26,600	W	W
Grade-A	do.	53	105,000	53	105,000	53	104,000
Salt		2,660	108,000	2,770	113,000	2,950	118,000
Sand and gravel: Construction		11,200	29,600	11,100	29,400	11,500	31,300
Stone:							
Crushed		21,500	103,000	20,400	95,800	22,100	110,000
Dimension 5/	metric tons	23,700	1,730	19,800	1,810	21,400	2,100
Combined value of gypsum (crude), pumice and pumicite, sand and gravel (industrial), stone (dimension sandstone), and values indicated by symbol W		XX	11,900	XX	12,200	XX	40,600
Total		XX	497,000	XX	498,000	XX	530,000
Kentucky:							
Clays:							
Ball		W	W	117	W	70	W
Common		820	3,460	786	3,430	823	3,680
Gemstones		NA	W	NA	W	NA	5,910
Sand and gravel: Construction		9,140	32,200	8,710	31,700	7,310	25,600
Stone: Crushed		56,300	259,000	54,700 5/	230,000 5/	58,500 5/	243,000 5/
Combined value of cement, lime, stone [crushed (1995), crushed sandstone (1996)], and values indicated by symbol W		XX	134,000	XX	167,000 r/	XX	164,000
Total		XX	428,000	XX	432,000 r/	XX	442,000
Louisiana:							
Clays: Common		371	531 r/	384	548	382	548
Gemstones		NA	155	NA	175	NA	136
Salt		13,500	140,000	14,700	177,000	15,500	175,000
Sand and gravel:							
Construction		12,300	49,600	11,300	50,200	11,500	53,200
Industrial		454	9,320	572	10,500	706	12,100
Stone (crushed) 5/		707	7,710	2,540	26,700	2,290	23,900
Combined value of gypsum (crude), lime, stone [crushed miscellaneous (1996), crushed shell and miscellaneous (1994-95)], and sulfur (Frasch)		XX	144,000	XX	169,000	XX	128,000
Total		XX	351,000 r/	XX	434,000	XX	393,000
Maine:							
Gemstones		NA	235	NA	305	NA	223
Peat		W	W	15 10/	845 10/	18 10/	960 10/
Sand and gravel: Construction		5,890	24,400	6,420	26,900	6,440	27,500
Stone: Crushed		2,740	15,500	3,110	16,100	2,760	14,800
Combined value of cement, clays (common), stone [dimension (1994), dimension granite (1995-96)], and value indicated by symbol W		XX	20,900	XX	23,500	XX	25,000
Total		XX	61,000	XX	67,600	XX	68,600
Maryland:							
Cement: Portland		1,710	90,700	1,670	101,000	1,610	99,400 e/
Clays: Common		293	946	278	943	304	874
Gemstones		NA	1	NA	1	NA	1
Sand and gravel: Construction		8,920	61,200	9,700	61,700	9,700	61,400
Stone:							
Crushed		23,200 5/	157,000 5/	24,200	158,000	22,400 5/	142,000 5/
Dimension	metric tons	18,800 5/	1,550 5/	20,700	2,260	19,800	2,210
Combined value of other industrial minerals		XX	29,000	XX	(6/)	XX	26,000
Total		XX	340,000	XX	324,000 7/	XX	332,000

See footnotes at end of table.

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TABLE 5–Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Massachusetts:						
Clays: Common	W	W	31	W	W	W
Gemstones	NA	W	NA	W	NA	1
Sand and gravel: Construction	12,300	60,000	11,700	67,500	14,200	82,500
Stone:						
Crushed	10,400 5/	96,800 5/	11,100	97,400	11,800 5/	91,600 5/
Dimension metric tons	57,300	9,600	77,600	14,600	79,600	15,000
Combined value of lime, peat, sand and gravel (industrial), stone [crushed dolomite and sandstone (1994), crushed miscellaneous (1996)], and values indicated by symbol W	XX	11,100	XX	10,700	XX	11,100
Total	XX	178,000	XX	190,000	XX	200,000
Michigan:						
Cement:						
Masonry	235	17,700	229	16,700	232	20,400 e/
Portland	5,160	331,000	5,400	361,000	5,390	397,000 e/
Clays: Common	1,150	3,370	623	3,430	652	3,410
Gemstones	NA	2	NA	2	NA	1
Gypsum, crude	1,790	15,300	1,510	14,900	1,590	14,400
Iron ore, usable	13,800	W	13,500	W	W	W
Lime	637	33,000	653	34,600	584	30,300
Peat	156 r/	5,090	173 10/	5,510 10/	168 10/	4,650 10/
Sand and gravel:						
Construction	48,800	160,000	53,500	178,000	53,800	197,000
Industrial	2,870 r/	31,300	2,940	30,600	2,680	29,400
Stone:						
Crushed	35,000	113,000	37,500	127,000	38,600 5/	144,000 5/
Dimension metric tons	147 5/	35 5/	W	W	W	W
Combined values of bromine, copper (1994-95), iron oxide pigments (crude), magnesium compounds, potash, salt, silver (1994-95), stone [crushed granite and miscellaneous (1996), dimension dolomite and sandstone (1995-96), dimension sandstone (1994)], and values indicated by symbol W	XX	690,000 r/	XX	750,000 r/	XX	695,000
Total	XX	1,400,000 r/	XX	1,520,000 r/	XX	1,540,000
Minnesota:						
Clays:						
Common	W	W	27	W	11	W
Kaolin	W	W	21	W	–	–
Gemstones	NA	26	NA	26	NA	148
Iron ore, usable	43,300	1,060,000 r/	47,000	1,330,000 r/	46,700	1,330,000
Peat	37	3,010	24 10/	2,070 10/	20 10/	1,540 10/
Sand and gravel: Construction	29,500	90,000	31,900	99,400	31,800	107,000
Stone:						
Crushed	10,900	47,100	11,300 5/	47,400 5/	12,100	59,000
Dimension metric tons	16,900 4/	W	26,900	11,100	25,400	10,700
Combined value of lime, sand and gravel (industrial), stone [crushed quartzite and traprock (1995), dimension dolomite and granite (1994)], and values indicated by symbol W	XX	44,900	XX	40,400	XX	35,100
Total	XX	1,240,000 r/	XX	1,530,000 r/	XX	1,540,000
Mississippi:						
Clays:						
Ball	W	W	73	4,540	73	4,540
Bentonite	139	4,980	164	6,510	145	4,480
Common	644	6,190	616	6,080	534	3,610
Fuller's earth	410	29,400	378	26,900	379	27,800
Gemstones	NA	1	NA	1	NA	1
Sand and gravel: Construction	12,400	53,200	11,800	53,000	13,400	60,600
Stone: Crushed	1,900	7,500	1,990 5/	8,010 5/	2,180 5/	9,300 5/
Combined value of other industrial minerals	XX	33,900	XX	25,500	XX	33,500
Total	XX	135,000	XX	131,000	XX	144,000

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Missouri:							
Cement: Portland		4,730	265,000	4,360	270,000	4,530	293,000 e/
Clays							
Ball		--	--	--	--	13	W
Common		1,040	4,630	972	4,810	849	3,250
Fire		213	3,280	359	5,480	223	3,220
Fuller's earth		W	W	283	W	283	W
Copper 3/		8	18,900	7	22,800	W	W
Gemstones		NA	67	NA	58	NA	108
Lead 3/	metric tons	290,000	238,000	W	W	W	W
Sand and gravel:							
Construction		9,760	36,500	8,840	32,400	9,820	35,600
Industrial		559	9,970	W	W	W	W
Silver 3/	metric tons	40	6,860	W	W	W	W
Stone: Crushed		68,900	330,000	65,700 5/	305,000 5/	67,000	325,000
Zinc 3/	metric tons	42,000	45,600	W	W	W	W
Combined value of barite, cement (masonry), iron ore (usable), iron oxide pigments (crude), lime, stone [crushed granite (1995), dimension granite], and values indicated by symbol W		XX	128,000	XX	495,000	XX	589,000
Total		XX	1,090,000	XX	1,140,000 r/	XX	1,250,000
Montana:							
Clays: Common		28	W	33	90	34	W
Gemstones		NA	3,400	NA	938	NA	1,840
Gold 3/	kilograms	12,600	156,000	12,400	155,000	9,110	114,000
Iron ore, usable		--	--	5	60	--	--
Lead 3/	metric tons	9,940	8,140	8,350	7,790	7,970	8,580
Palladium	kilograms	6,440	29,400	5,260	22,000	6,100	25,500
Platinum	do.	1,960	25,300	1,590	20,800	1,840	23,500
Sand and gravel: Construction		7,360	28,800	8,870	34,900	9,260	35,800
Silver 3/	metric tons	71	12,000	77 r/	12,700 r/	W	W
Stone: Crushed		2,320	8,830	2,370 5/	9,920 5/	2,000	8,580
Zinc 3/	metric tons	21,000	22,800	22,700	27,900	19,400	21,900
Combined value of barite (1994), cement, clays (bentonite, fire), copper, garnet (industrial), lime, molybdenum, peat, sand and gravel (industrial), stone [crushed quartzite (1995), dimension miscellaneous], talc and pyrophyllite, and values indicated by symbol W		XX	249,000	XX	283,000 r/	XX	251,000
Total		XX	543,000	XX	574,000 r/	XX	491,000
Nebraska:							
Clays: Common		206	867	232	1,130	277	1,140
Gemstones		NA	W	NA	W	NA	3
Lime		24	904	20	803	13	553
Sand and gravel: Construction		15,000	49,200	13,700	47,100	12,900	44,300
Stone: Crushed		6,890	41,600	6,590	41,800	6,370	39,800
Combined value of other industrial minerals		XX	53,600	XX	55,500	XX	62,100
Total		XX	146,000	XX	146,000	XX	148,000
Nevada:							
Barite		284 11/	5,020 11/	W	W	W	W
Clays:							
Bentonite		7	2,860	6	477	6	580
Kaolin		W	W	W	W	25	W
Copper 3/		6	15,800	6	19,800	W	W
Gemstones		NA	160	NA	306	NA	234
Gold 3/	kilograms	214,000	2,700,000	210,000 r/	2,620,000 r/	213,000	2,680,000
Sand and gravel:							
Construction		22,700	106,000	22,500	110,000	22,400	113,000
Industrial		572	W	W	W	W	W
Silver 3/	metric tons	673	115,000	693 r/	115,000 r/	605	101,000
Stone: Crushed		2,310	20,600	2,410	21,400	3,080	25,200
Zeolites	metric tons	W	NA	W	NA	1,220	NA

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Nevada--Continued:						
Combined value of brucite, cement (portland), clays (fuller's earth), diatomite, gypsum (crude), lime, lithium minerals, magnesite, mercury, perlite (crude), salt, and values indicated by symbol W	XX	149,000	XX	180,000	XX	315,000
Total	XX	3,110,000	XX	3,060,000 r/	XX	3,230,000
New Hampshire:						
Clays: Common	3	16	3	16	3	16
Gemstones	NA	21	NA	9	NA	6
Sand and gravel: Construction	7,120	32,600	7,190	34,300	7,620	36,500
Stone:						
Crushed 5/	1,390	7,470	2,150	9,150	1,430	8,650
Dimension metric tons	35,300	6,300	23,000	6,290	29,000	6,500
Total 7/	XX	46,400	XX	49,800	XX	51,700
New Jersey:						
Clays: Common	W	W	82	135	74	125
Gemstones	NA	1	NA	1	NA	1
Sand and gravel:						
Construction	16,100	100,000	14,000	80,300	13,200	70,400
Industrial	1,690	30,600	1,760	31,000	1,680	30,300
Stone: Crushed	19,800	154,000	21,000	132,000	21,400	145,000
Combined value of other industrial minerals	XX	4,460	XX	(6/)	XX	(6/)
Total	XX	289,000	XX	243,000 7/	XX	246,000 7/
New Mexico:						
Clays: Common	127	269	127	274	32	165
Copper 3/	234	574,000	250	764,000 r/	W	W
Gemstones	NA	14	NA	22	NA	54
Potash (K_2O)	2,450	219,000	2,330	209,000	2,430	225,000
Pumice and pumicite metric tons	129,000	1,050	W	W	102,000	527
Sand and gravel: Construction	10,400	47,400	10,400	50,700	9,880	48,500
Silver 3/ metric tons	22	3,750	20	3,300	W	W
Stone: Crushed	3,550 5/	20,000 5/	3,660	18,800	3,480 5/	18,800 5/
Combined value of cement [masonry (1994), portland], clays (fire), gold, gypsum (crude), iron ore (usable), mica (crude), molybdenum, perlite (crude), salt, stone [crushed quartzite and traprock (1994, 1996), dimension granite and marble (1995-96), dimension granite, marble, and miscellaneous (1994)], and values indicated by symbol W	XX	65,100	XX	83,900	XX	699,000
Total	XX	930,000	XX	1,130,000	XX	992,000
New York:						
Cement:						
Masonry	82	6,020	90	7,210	W	W
Portland	2,650	139,000	2,530	205,000	2,570	157,000 e/
Clays: Common	507	9,270	563	12,500	652	14,000
Gemstones	NA	W	NA	W	NA	291
Peat	W	12	W	W	W	W
Salt	6,060	233,000	4,480	185,000	4,420	203,000
Sand and gravel: Construction	28,000	138,000	27,300	134,000	28,100	145,000
Stone:						
Crushed	39,400	239,000	39,500	204,000	43,600	233,000
Dimension metric tons	24,600 5/	7,370 5/	32,800	8,440	34,400	8,120
Combined value of garnet (industrial), gypsum (crude), lead, sand and gravel (industrial), silver, stone [dimension granite and quartzite (1994)], talc and pyrophyllite, wollastonite, zinc, and values indicated by symbol W	XX	117,000	XX	130,000	XX	130,000
Total	XX	889,000	XX	886,000	XX	891,000

See footnotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
North Carolina:							
Clays: Common		2,530	12,500	2,430	12,500	2,400	12,400
Feldspar	metric tons	488,000	17,600	497,000	18,400	481,000	18,400
Gemstones		NA	565	NA	4,440	NA	693
Mica, crude		68	3,270	74	3,690	62	4,900
Peat		21	W	19 10/	340 10/	15 10/	311 10/
Sand and gravel:							
Construction		11,100	50,700	10,100	50,100	10,000	50,500
Industrial		1,460	24,200	1,330	21,900	1,500	21,700
Stone:							
Crushed		53,900 5/	351,000 5/	57,300	384,000	57,200	394,000
Dimension	metric tons	33,700 5/	12,500 5/	41,100 5/	15,400 5/	37,300	14,300
Combined value of clays (kaolin), lithium minerals, olivine, phosphate rock, stone [dimension quartzite, sandstone, slate and miscellaneous (1994-95)], talc and pyrophyllite, and value indicated by symbol W		XX	231,000	XX	225,000	XX	172,000
Total		XX	703,000	XX	735,000	XX	690,000
North Dakota:							
Clays: Common		59	W	59	W	59	W
Gemstones		NA	W	NA	W	NA	3
Lime		W	6,590	W	W	W	W
Sand and gravel: Construction		6,810	18,500	8,420	23,900	8,320	23,800
Combine value of peat, sand and gravel (industrial), and values indicated by symbol W		XX	199	XX	7,300	XX	7,060
Total		XX	25,300	XX	31,200	XX	30,800
Ohio:							
Cement: Portland		1,050	69,700	1,050	72,700	W	W
Clays:							
Common		1,940	7,950	1,840	7,560	1,960	7,450
Fire		142	4,550	89	3,140	103	3,230
Gemstones		NA	43	NA	3	NA	153
Lime		1,850	113,000	1,920	117,000	2,020	107,000
Sand and gravel:							
Construction		47,700	205,000	45,300	196,000	46,600	215,000
Industrial		1,260	27,700	1,270	28,800	1,270	29,800
Stone:							
Crushed		56,400	251,000	60,900	265,000	63,600	291,000
Dimension	metric tons	W	W	17,900	1,670	19,800	2,060
Combined value of cement (masonry), clays [ball (1994)], gypsum (crude), peat, salt, silica stone (1994, 1996), stone [dimension limestone and sandstone (1994)], and values indicated by symbol W		XX	201,000	XX	200,000	XX	314,000
Total		XX	880,000	XX	891,000	XX	969,000
Oklahoma:							
Cement:							
Masonry		91	7,410	95	7,250	101	8,850 e/
Portland		1,680	102,000	1,740	110,000	1,750	118,000 e/
Clays:							
Common		771	3,910	674	3,580	799	4,090
Fire		--	--	--	--	23	W
Gemstones		NA	W	NA	W	NA	603
Gypsum, crude		2,890	17,000	2,830	17,000	2,690	16,500
Iodine, crude	metric tons	1,630	12,800	1,210	12,500	1,270	14,600
Sand and gravel:							
Construction		8,480	27,200	7,800	25,100	7,910	27,700
Industrial		1,230	24,000	1,250	25,400	1,350	27,200
Stone:							
Crushed		29,900	125,000	31,100	125,000	28,300 5/	117,000 5/
Dimension	metric tons	3,980 5/	1,250 5/	9,170 5/	2,350 5/	9,710	2,220

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Oklahoma--Continued:							
Combined value of feldspar, helium [crude (1995-96), Grade-A (1996)], lime, salt, stone [crushed shell and traprock (1995-96), dimension quartzite and sandstone (1995), dimension sandstone (1994)], tripoli, and values indicated by symbol W		XX	19,400	XX	28,700	XX	32,300
Total		XX	340,000	XX	357,000	XX	369,000
Oregon:							
Clays:							
Bentonite		25	1,150	17	917	33	1,530
Common		215	414	222	354	213	154
Copper 3/		(9/)	260	--	--	--	--
Gemstones		NA	2,160	NA	4,570	NA	6,730
Nickel ore	metric tons	--	--	1,560	W	1,330 12/	W
Pumice and pumicite	do.	220,000	2,760	W	W	W	W
Sand and gravel: Construction		18,400	83,600	18,200	85,000	18,300	86,800
Silver 3/	metric tons	(9/)	10	--	--	--	--
Stone: Crushed		18,900	90,100	20,700	95,700	22,000	102,000
Talc and pyrophyllite	metric tons	W	W	W	W	64	84
Zinc 3/	do.	118	128	--	--	--	--
Combine value of cement (portland), diatomite, emery, gold (1994), lime, and values indicated by symbol W		XX	62,100	XX	52,500	XX	67,100
Total		XX	243,000	XX	239,000	XX	265,000
Pennsylvania:							
Cement:							
Masonry		245	19,300	267	21,200	274	28,000 e/
Portland		5,630	315,000	5,610	355,000	5,670	418,000 e/
Clays:							
Common		797	3,230	736	2,430	753	2,420
Kaolin		14	815	14	815	14	815
Gemstones		NA	1	NA	1	NA	1
Lime		1,590	95,500	1,640	107,000	1,530	105,000
Peat		10	296	11 10/	294 10/	4 10/	166 10/
Sand and gravel: Construction		15,900	89,700	17,100	93,100	15,100	85,600
Stone:							
Crushed		76,700	462,000	80,900	492,000	87,400	518,000
Dimension	metric tons	43,700 5/	7,280 5/	57,600	12,300	54,300	11,800
Combined value of other industrial minerals		XX	13,300	XX	(6/)	XX	(6/)
Total		XX	1 010,000	XX	1 080,000 7/	XX	1 170,000 7/
Rhode Island:							
Gemstones		NA	1	NA	1	NA	1
Sand and gravel: Construction		2,310	14,200	2,790	21,500	1,990	13,300
Stone: Crushed		1,610	12,200	1,250	9,140	1,440	9,680
Total 7/		XX	26,300	XX	30,700	XX	23,000
South Carolina:							
Cement:							
Masonry		W	W	W	W	286	27,100 e/
Portland		2,210	143,000	2,210	156,000	2,370	186,000 e/
Clays:							
Common		1,130	4,670	1,220	4,910	1,260	4,860
Fire		--	--	24	W	24	W
Kaolin		388 13/	25,700 13/	373	16,800	387	18,100
Gemstones		NA	W	NA	W	NA	16
Sand and gravel:							
Construction		8,600	26,100	8,880	29,000	8,780	29,000
Industrial		699	18,100	839	20,500	761	19,500
Stone: Crushed		20,500 5/	131,000 5/	22,000	132,000	23,800	146,000

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
South Carolina--Continued:							
Combined value of gold, manganiferous ore (1994-95), mica (crude), peat (1994-95), silver, stone [crushed marble (1994), dimension granite], vermiculite and values indicated by symbol W		XX	93,900	XX	88,700	XX	62,700
Total		XX	442,000	XX	447,000	XX	493,000
South Dakota:							
Clay: Common		W	W	136	W	147	W
Gemstones		NA	110	NA	173	NA	98
Gold 3/	kilograms	W	W	17,100	214,000	W	W
Sand and gravel: Construction		7,700	23,700	8,730	26,200	8,750	27,700
Silver 3/	metric tons	4	696	4	668	5	816
Stone: Crushed		5,490 5/	24,500 5/	5,420 5/	25,700 5/	5,640	28,700
Combined value of cement, feldspar, iron ore (usable), lime, mica (crude), stone [crushed granite and miscellaneous (1995), crushed miscellaneous (1994), dimension granite], and values indicated by symbol W		XX	274,000	XX	65,300	XX	300,000
Total		XX	323,000	XX	332,000	XX	357,000
Tennessee:							
Clays:							
Ball		665	28,600	663	29,000	679	29,000
Kaolin		--	--	1	W	32	W
Gemstones		NA	23,100	NA	16,900 r/	NA	12,900
Sand and gravel:							
Construction		8,710	38,000	8,020	36,700	8,380	35,300
Industrial		660	11,600	918	14,700	747	13,900
Stone: Crushed		49,200	265,000	52,600	286,000	55,100	305,000
Combined value of barite, cement, clays [bentonite (1994), common, fuller's earth], copper, lead, lime, silver, stone (dimension marble), zinc, and values indicated by symbol W		XX	235,000	XX	282,000	XX	266,000
Total		XX	602,000	XX	665,000 r/	XX	662,000
Texas:							
Cement:							
Masonry		258	18,200	202	17,600	216	20,300 e/
Portland		8,620	456,000	8,090	499,000	8,240	532,000 e/
Clays:							
Ball		W	W	101	2,800	101	W
Common		2,190	13,700	2,320	15,500	2,290	15,000
Kaolin		W	W	36	7,700	28	W
Gemstones		NA	448	NA	353	NA	511
Gypsum, crude		1,870	10,100	1,880	16,200	2,240	12,100
Helium, crude	million cubic meters	7	7,050	5	4,730	W	W
Lime		1,210	76,200	1,370	85,800	1,360	86,300
Salt		8,760	76,500	9,110	85,000	9,700	88,900
Sand and gravel:							
Construction		56,700	242,000	61,100	271,000	61,300	278,000
Industrial		1,570	37,900	1,600	40,300	1,420	38,200
Stone:							
Crushed		76,100	300,000	81,100	310,000	86,500	341,000
Dimension	metric tons	W	W	54,000	13,300	86,600	21,100
Talc and pyrophyllite	do.	225,000	5,860	294,000	5,840	225,000	5,100
Combined value of clays [bentonite (1994-95), fuller's earth], helium (Grade-A), iron ore [usable (1994)], magnesium compounds, magnesium metal, sodium sulfate (natural), stone [dimension granite and limestone (1994)], sulfur (Frasch), and values indicated by symbol W		XX	295,000	XX	301,000	XX	293,000
Total		XX	1,540,000	XX	1,680,000	XX	1,730,000

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Utah:							
Beryllium concentrates	metric tons	4,330	5	5,040	6	5,260	6
Clays:							
Bentonite		W	W	38	W	W	1,400
Common		243	3,410	386	4,280	298	4,510
Fuller's earth		--	--	--	--	W	32
Gemstones		NA	620	NA	939	NA	1,150
Iron ore, usable		W	W	144	1,700	--	--
Salt		1,680	56,700	2,160	54,800	1,720	70,400
Sand and gravel: Construction		21,100	69,600	23,800	80,200	24,700	80,500
Stone: Crushed		4,540	19,800	4,140	14,800	4,380	19,100
Combined value of cement, copper, gold, gypsum (crude), helium (Grade-A), lime, magnesium compounds, magnesium metal, mercury, molybdenum, phosphate rock, potash, silver, stone (dimension quartzite and sand stone), and values indicated by symbol W		XX	1,370,000	XX	1,700,000	XX	1,560,000
Total		XX	1,520,000	XX	1,850,000	XX	1,730,000
Vermont:							
Asbestos	metric tons	1,130	920	--	--	--	--
Gemstones		NA	1	NA	1	NA	1
Sand and gravel: Construction		3,890	14,500	3,220	11,000	3,870	15,200
Stone:							
Crushed		4,170	23,700	4,420	20,700	4,560	22,800
Dimension	metric tons	78,900	23,200	100,000	28,700	99,600	27,900
Total 7/		XX	62,300	XX	60,400	XX	66,000
Virginia:							
Cement: Portland		930	54,700	W	W	W	W
Clays:							
Common		870	3,250	844	3,200	883	3,220
Fuller's earth		W	W	46	W	46	W
Gemstones		NA	W	NA	W	NA	11
Lime		742	40,200	731	41,900	766	45,700
Sand and gravel: Construction		8,060	33,400	9,710	42,300	9,780	45,800
Stone:							
Crushed		56,700	327,000	55,400	326,000	59,700	351,000
Dimension	metric tons	108 5/	13 5/	W	W	W	W
Combine value of cement (masonry), feldspar, gypsum (crude), iron oxide pigments (crude), kyanite, sand and gravel (industrial), stone [dimension dolomite, slate, and traprock (1995), dimension dolomite, granite, slate, and traprock (1996), dimension granite and slate (1994)], talc and pyrophyllite, vermiculite, and values indicated by symbol W		XX	43,600	XX	101,000	XX	103,000
Total		XX	502,000	XX	515,000	XX	549,000
Washington:							
Cement: Portland		W	W	W	W	1,160	78,900 e/
Clays: Common		246	1,140	220	1,040	218	1,070
Gemstones		NA	1,050	NA	53	NA	36
Gold 3/	kilograms	7,410	91,800	W	W	W	W
Lime		239	W	W	W	W	W
Peat	metric tons	3	111	2 10/	87 10/	W	W
Sand and gravel: Construction		39,600	165,000	37,700	155,000	37,900	162,000
Stone: Crushed		14,700	91,900	15,800 5/	76,800 5/	15,400	81,400
Combined value of cement (masonry), clays [fire (1994)], diatomite, magnesium metal, olivine, sand and gravel (industrial), silver (1994), stone [crushed dolomite, limestone, and marble (1995), dimension miscellaneous], and values indicated by symbol W		XX	225,000	XX	350,000	XX	212,000
Total		XX	576,000	XX	582,000	XX	535,000

See foonotes at end of table.

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TABLE 5--Continued
NONFUEL RAW MINERAL PRODUCTION 1/ IN THE UNITED STATES, BY STATE 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
West Virginia:						
Clays: Common	138	291	184	365	199	369
Gemstones	NA	1	NA	1	NA	1
Sand and gravel: Construction	1,380	5,970	1,800	7,650	1,730	7,710
Stone: Crushed	12,300 5/	99,300	11,800 5/	75,000 5/	12,700 5/	78,400 5/
Combined value of cement, lime, peat, salt, sand and gravel (industrial), and stone [crushed dolomite, dimension sandstone]	XX	75,500	XX	97,700	XX	98,600
Total	XX	181,000	XX	181,000	XX	185,000
Wisconsin:						
Gemstones	NA	53	NA	65	NA	505
Lime	507	30,300	568	33,900	551	32,000
Peat	2	61	W	W	W	W
Sand and gravel:						
Construction	29,200	91,500	32,200	102,000	32,600	105,000
Industrial	1,630	32,400	1,670	33,300	1,660	32,300
Silica stone 8/ metric tons	45	80	W	W	W	W
Stone:						
Crushed	28,600	115,000 5/	26,000	108,000	26,000	113,000
Dimension metric tons	125,000	14,100	128,000	14,500	143,000	16,600
Combined value of copper, gold, silver, stone [crushed quartzite (1994)], and values indicated by symbol W	XX	126,000	XX	124,000	XX	96,800
Total	XX	409,000	XX	416,000	XX	396,000
Wyoming:						
Clays:						
Bentonite	2,530	91,300	2,940	89,900	3,030	98,400
Common	W	W	30	W	30	W
Gemstones	NA	13	NA	11	NA	11
Sand and gravel: Construction	3,210	13,100	3,860	17,500	3,420	14,700
Stone: Crushed	5,040	29,700	4,670	27,500	5,180	30,000
Combined value of cement (portland), gypsum (crude), helium (Grade-A), lime, soda ash, and values indicated by symbol W	XX	746,000	XX	838,000	XX	935,000
Total	XX	880,000	XX	973,000	XX	1,080,000
Undistributed:						
Alaska (1995), Connecticut, Delaware, Hawaii, Maryland (1995), New Hampshire, New Jersey (1995-96), Pennsylvania (1995-96), Rhode Island, and Vermont	XX	14,700	XX	123,000 r/	XX	30,200

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data, value included with "Combined value." XX Not applicable.

1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Recoverable content of ores, etc.

4/ Data collected by State.

5/ Excludes certain stones; kind and value included with "Combined value."

6/ Value excluded to avoid disclosing company proprietary data.

7/ Partial total, excludes values which must be concealed to avoid disclosing company proprietary data. Withheld values included with "Undistributed."

8/ Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

9/ Less than 1/2 unit.

10/ Data series changed to production beginning in 1995, prior years data may not be comparable.

11/ Excludes certain barites; kind and value included with "Combined value."

12/ Quantity of local ore fed to smelter after rejection of lower grade material. The smelter uses lateritic ore imported from New Caledonia in addition to lateritic ore mined on Nickel Mountain. In 1995, the smelter was idle from January to the beginning of May because of low nickel prices.

13/ Excludes certain clays; kind and value included with "Combined value."

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TABLE 6
NONFUEL RAW MINERAL PRODUCTION IN THE COMMONWEALTH OF PUERTO RICO AND ISLANDS ADMINISTERED BY THE UNITED STATES 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1994 Quantity	1994 Value	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Puerto Rico:							
Cement: Portland	metric tons	W	W	1,410	W	1,550	W
Clays: Common		119	338	W	W	W	W
Lime		23	2,970	23	2,970	38	5,050
Salt		--	--	--	--	45	1,500
Stone: Crushed		10,500	78,400	15,300	107,000	13,200	52,500
Combined value of sand and gravel (industrial), stone (dimension), and values indicated by symbol W		XX	138,000	XX	146,000	XX	153,000
Total		XX	220,000	XX	256,000	XX	212,000
Administered Islands:							
American Samoa: Stone, crushed		84	(3/)	(3/)	(3/)	--	--
Guam: Stone, crushed		2,150	12,700	2,060	17,400	1,660	13,800
Total 4/		XX	12,700	XX	17,400	XX	13,800

W Withheld to avoid disclosing company proprietary data; value included with "Combined value" data. XX Not applicable.
1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Withheld to avoid disclosing company proprietary data.
4/ Total does not include values of items withheld.

TABLE 7
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	1,610,000	3,900,000	1,500,000	3,420,000
Manufactures	do.	132,000	386,000	134,000	410,000
Antimony:					
Metal, alloys, waste and scrap	do.	1,610	5,010	462	1,760
Oxide, antimony content	do.	6,590	19,900	3,990	18,600
Arsenic metal	do.	430	2,130	36	954
Bauxite and alumina:					
Alumina, calcined equivalent		1,040	353,000	918	374,000
Bauxite:					
Calcined		22	3,860	40	7,830
Crude and dried		86	8,010	92	9,090
Beryllium, alloys, wrought or unwrought, and waste and scrap	kilograms	61,300	5,800	56,700	4,510
Bismuth, metal, alloys, and waste and scrap, metal content	do.	261,000	3,430	151,000	1,930
Cadmium:					
Metal	do.	1,050,000	7,160	201,000	1,030
Sulfide	do.	506,000	283	797,000	399
Chromium:					
Chemicals	metric tons	37,500	53,400	47,000	66,100
Chromite ore and concentrate	do.	17,800	3,430	69,400	11,100
Metals, alloys, and ferroalloys	do.	10,100	20,300	17,200	26,800
Pigments and preparations	do.	1,260	6,020	2,100	6,920
Cobalt:					
Metal:					
Unwrought, powders, waste and scrap, and mattes and other intermediate products of metallurgy	do.	898	49,000	1,310	65,500
Wrought and cobalt articles	do.	485	17,800	529	23,500
Oxides and hydroxides	do.	271	8,850	346	10,200
Other forms, acetates and chlorides	do.	859	7,080	446	4,040
Columbium (niobium) and tantalum:					
Columbium:					
Ferrocolumbium	do.	529	4,450	254	1,490
Ores and concentrates	do.	96	869	11	185

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals--Continued:					
Tantalum:					
Ores and concentrates, includes synthetic	metric tons	2	55	91	764
Unwrought, alloys, metal, powders, and waste and scrap	do.	211 r/	25,800	269	40,200
Wrought	do.	111	33,000	99	32,100
Copper:					
Scrap, alloyed and unalloyed	do.	456,000	722,000	392,000	616,000
Semimanufactures	do.	104,000	407,000	123,000	447,000
Unmanufactured, does not include unalloyed scrap, copper content	do.	520,000	1,180,000	424,000	750,000
Ferroalloys not listed elsewhere:					
Ferrophosphorous	do.	6,470	2,730	4,420	1,760
Ferrotitanium and ferrosilicon-titanium	do.	XX	XX	777	2,330
Ferrozirconium	do.	130	260	101	228
Ferroalloys, other	do.	3,590	6,510	2,970	6,080
Gold:					
Bullion, refined	kilograms	277,000 r/	3,360,000	406,000	5,010,000
Doré and precipitates	do.	69,700	841,000	65,100	696,000
Ores and concentrates	do.	352	3,480	375	3,730
Waste and scrap	do.	82,400	762,000	89,900	853,000
Iron ore		5,270	184,000	6,260	232,000
Iron and steel:					
Cast iron and steel products		250	461,000	240	488,000
Fabricated steel products		914	2,510,000	1,030	2,980,000
Steel mill products		6,420	4,650,000	4,560	4,060,000
Iron and steel scrap:					
Ferrous, includes tinplate and terplate, excludes used rails for rerolling and other uses, and ships boats, and other vessels for scrapping		10,400	1,700,000	8,440	1,340,000
Pig iron, all grades		54	6,450	48	7,040
Direct-reduced iron, steelmaking grade		5	490	3	304
Ships, boats, and other vessels for scrapping		6	875	24	2,710
Used rails for rerolling and other uses, includes mixed (new plus used), rails		23	5,960	21	6,900
Lead, lead content:					
Ash and residues	metric tons	8,040	4,760	19,400	9,930
Ore and concentrate	do.	65,500	19,600	59,700	17,400
Scrap, gross weight	do.	105,000	31,000	85,300 3/	18,400
Unwrought lead and lead alloys	do.	48,200	35,000	85,200	104,000
Wrought lead and lead alloys	do.	9,020	24,500	16,700	40,600
Magnesium:					
Alloys, gross weight	do.	6,080	18,400	6,970	25,900
Metal	do.	21,500	59,300	17,000	57,300
Powder, sheets, tubing, ribbons, wire, and other forms, gross weight	do.	7,200	20,500	7,970	20,700
Waste and scrap	do.	3,540	8,350	8,500	20,900
Manganese:					
Ferromanganese, all grades	do.	11,000	10,100	9,800	8,850
Metal, including alloys, waste and scrap	do.	5,640	12,600	5,840	14,500
Ore and concentrates with 20% or more manganese	do.	15,400	1,750	31,600	4,000
Silicomanganese	do.	7,840	5,650	5,270	4,390
Mercury and mercury-bearing waste and scrap	do.	179	770	45	344
Molybdenum, molybdenum content:					
Ferromolybdenum	do.	695 r/	14,600	985	9,930
Ore and concentrates, including roasted and other	do.	44,600	564,000 r/	45,000	232,000
Oxides and hydroxides, gross weight	do.	2,840	42,200	1,790	14,000
Molybdates, all	do.	2,180 r/	36,000	1,340	7,620
Powder, gross weight	do.	306 r/	11,100	210	8,260
Unwrought, gross weight	do.	629 r/	9,770 r/	601	7,110
Wire, gross weight	do.	303 r/	17,700	174	12,300
Wrought, gross weight	do.	182 r/	12,700	185	11,000
Nickel, nickel content:					
Alloyed, gross weight	do.	18,900	289,000	23,500	326,000

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals--Continued:					
Nickel, nickel content--Continued:					
Unwrought:					
Primary	metric tons	9,750	134,000	13,100	162,000
Secondary	do.	41,800	384,000	33,600	290,000
Wrought	do.	476	5,750	440	6,370
Platinum-group metals	kilograms	50,600	404,000 r/	48,800	334,000
Rare-earths, rare-earth oxide content:					
Cerium compounds	do.	5,120,000	35,500	6,100,000	37,900
Rare-earth compounds	do.	1,550,000	13,400	2,210,000	15,500
Rare-earth metals, including scandium and yttrium	do.	370,000	3,690	208,000	4,540
Ferrocerium and other pyrophoric alloys	do.	3,910,000	14,200	4,970,000	21,100
Selenium, metal, waste and scrap, selenium content	do.	270,000 r/	2,290 r/	322,000	2,670
Silicon:					
Ferrosilicon	metric tons	41,600	40,600	51,700	46,100
Metal	do.	25,100	196,000	17,000	209,000
Silver, contained silver:					
Ores and concentrates	kilograms	741	233	1,520	316
Doré and precipitates	do.	72,100	23,500	43,300	8,030
Bullion, refined	do.	2,810,000	497,000	2,900,000	536,000
Waste and scrap, gross weight	do.	1,580,000	304,000	1,280,000	236,000
Thorium and thorium-bearing materials:					
Compounds	do.	75	25	58	14
Ore, monazite concentrate	do.	--	--	2,000	3
Tin:					
Ingots and pigs	metric tons	2,790	17,300	3,670	21,000
Tin scrap and other tin bearing material, except tinplate scrap, includes rods, profiles, wire, powders, flakes, tubes, and pipes	do.	57,600	56,600	56,800	61,300
Tinplate and terneplate	do.	307,000	185,000	338,000	210,000
Titanium:					
Metal, sponge and scrap	do.	3,680	10,200	3,940	11,900
Other unwrought, billet, blooms, sheet bars, ingot, other	do.	2,560	46,500	4,290	84,300
Wrought, bars, rods, other	do.	4,590 r/	163,000 r/	4,530	203,000
Ores and concentrates	do.	32,300	12,000	15,500	5,890
Pigments, dioxide pigments and oxides	do.	342,000	589,000	332,000	572,000
Tungsten, tungsten content:					
Ore and concentrate	do.	20 r/	159 r/	72	539
Ammonium paratungstate	do.	238	2,760	150	1,310
Carbide powder	do.	1,660	37,000	1,290	32,000
Metal and alloy powder	do.	485 r/	11,800	240	7,280
Miscellaneous tungsten-bearing materials, metal and alloy wire, unwrought metal and alloy in crude form, waste and scrap, other metal, ferrotungsten and ferrosilicon tungsten, wrought metal, other tungsten compounds (includes only other tungstates)	do.	1,080 r/	30,200 r/	866	29,000
Vanadium:					
Aluminum-vanadium master alloy, includes vanadium metal	kilograms	660,000	8,190	310,000	4,410
Ferrovanadium, vanadium content	do.	340,000	6,550	479,000	8,830
Vanadium pentoxide, anhydride, vanadium content	do.	229,000	1,830	241,000	2,060
Other oxides and hydroxides of vanadium, vanadium content	do.	1,010,000	7,200	2,670,000	12,400
Zinc:					
Compounds, lithopone, chlorides, compounds n.s.p.f., oxide, sulfate, and sulfide	metric tons	15,400	18,000	14,200	21,800
Ores and concentrates, zinc content	do.	424,000	201,000	425,000	190,000
Refined slab	do.	3,080	4,340	1,970	2,350
Rolled	do.	5,180	6,000	5,020	5,350
Zirconium and hafnium:					
Zirconium, ore and concentrates	do.	40,300	20,000	35,000	22,800
Zirconium, oxide includes germanium oxides and zirconium oxides.	do.	1,680	9,390	1,480	10,900
Zirconium, unwrought and waste and scrap	do.	164	4,520	136	3,550
Total		XX	26,500,000 r/	XX	26,800,000

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Industrial minerals:					
Abrasives, manufactured:					
Fused aluminum oxide	metric tons	11,000	28,000	11,900	18,000
Silicon carbide	do.	19,900	16,900	14,200	15,600
Metallic abrasives	do.	31,100	16,200	24,900	15,200
Boron carbide	do.	--	--	7	600
Asbestos, includes reexports:					
Manufactured		XX	180,000	XX	163,000
Unmanufactured	metric tons	14,600	6,010	15,400	5,310
Barite, natural barium sulfate	do.	15,600	2,020	30,500	3,190
Boron:					
Boric acid		75 r/	68,100	42	35,300
Sodium borates		588	227,000	381	133,000
Bromine:					
Compounds, contained bromine	metric tons	11,200	19,900	1,110	22,100
Elemental	do.	3,220	3,790	2,920	3,970
Cement: Hydraulic and clinker		759	53,000	803	58,200
Clays:					
Ball		28	1,780	80	5,270
Bentonite		733	75,000	746	80,600
Fire		281	28,800	295	28,500
Fuller's earth		63	8,980	112	13,200
Kaolin		3,240	560,000	3,240	555,000
Other, includes chamotte or dinas earth, activated clays and earths, and artificially activated clays		338	138,000	364	142,000
Diamond, industrial:					
Industrial diamond stones	thousand carats	5,180 r/	29,900 r/	3,260	26,600
Powder and grit	do.	101,000	98,200 r/	108,000	94,300
Diatomite		144	43,300	143	42,000
Feldspar	metric tons	14,700	1,970	10,200	1,390
Fluorspar	do.	41,800	5,550	61,600	8,110
Garnet, industrial	do.	9,000 e/	XX	13,000 e/	XX
Gemstones, includes reexports		XX	2,530,000	XX	2,700,000
Graphite, nautral and artificial 4/	metric tons	90,600	66,400	92,500	68,000
Gypsum:					
Boards		64	17,300	80	22,800
Crude		79	4,240	136	6,120
Plasters		159	23,900	142	25,800
Other		XX	29,600	XX	26,700
Helium: Grade-A	million cubic meters	28	54,900	23	45,200
Iodine, crude/sublimed and potassium iodine	metric tons	1,220	13,000	2,400	19,100
Iron oxide pigments and hydroxides:					
Pigment grade	do.	17,500	24,900	16,000	23,200
Other grade	do.	159,000	108,000	27,200	41,700
Lime		72	8,490	50	5,600
Lithium chemicals:					
Carbonate	metric tons	6,550	22,500	7,890	28,400
Hydroxide	do.	4,060	17,400	4,390	18,900
Magnesium compounds:					
Compounds, chlorides, hydroxide and peroxide, and sulfates	do.	27,000	9,830	27,600	12,000
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	2,280	1,200	19,600	6,770
Dead-burned and fused magnesia	do.	74,800	28,600	72,600	27,500
Magnesite, crude	do.	31,900	4,120	33,000	4,240
Other magnesia	do.	12,400	8,300 r/	16,600	12,500
Mica:					
Scrap and flake:					
Powder	do.	6,280	3,160	5,830	3,070
Waste	do.	952	294	1,710	495
Sheet:					
Unworked	do.	198	389	225	542
Worked	do.	737	11,700	606	10,700
Nitrogen, major compounds		13,800	NA	12,700 p/	NA

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Industrial minerals--Continued:					
Peat		20 r/	2,410 r/	19	1,990
Perlite	metric tons	40,000 e/	1,120	38,000 e/	1,070
Phosphate rock:					
Elemental phosphorous	do.	13,700	24,100	12,600	25,500
Phosphate rock, ground and unground		2,990	NA	1,570	NA
Phosphates, diammonium and monoammonium		11,300	NA	9,430	NA
Phosphoric acid		575	NA	570	NA
Superphosphates, concentrated		714	NA	681	NA
Potash:					
Potassium chloride, all grades	metric tons	297,000	NA	393,000	NA
Potassium sulfate	do.	290,000	NA	283,000	NA
Potassium magnesium sulfate	do.	339,000	NA	411,000	NA
Potassium nitrate	do.	11,600	NA	14,300	NA
Pumice and pumicite		16	6,700	13	6,300
Salt		670	34,400	869	39,300
Sand and gravel:					
Construction:					
Gravel		453	5,540	368	5,160
Sand		850	19,200	1,160	18,100
Industrial		1,870	106,000	1,430	113,000
Silica:					
Quartz crystal, cultured electronic- and optical-grade	metric tons	35	10,900	89	22,200
Tripoli and special silica, special silica stone products	do.	XX	6,500	XX	6,700
Soda ash		3,570	445,000	3,840	508,000
Sodium sulfate		66	7,250	86	9,140
Stone:					
Crushed		6,040,000	39,300	3,270,000	36,300
Dimension		NA	51,800	NA	49,500
Strontium compounds, precipitated carbonate, oxide, hydroxide, and peroxide	kilograms	1,730	929 r/	1,550	1,080
Sulfur:					
Elemental		906	66,200	855	51,700
Sulfuric acid, 100% H_2SO_4	metric tons	170,000	12,800	117,000	12,400
Talc, excludes talcum in (package), face, and compact		183	37,100	192	37,900
Vermiculite		6	696 e/	8	1,170 e/
Wollastonite		NA	NA	4,080	1,020 e/
Total		XX	5,480,000	XX	5,530,000
Grand total		XX	32,000,000 r/	XX	32,300,000

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data not available at time of table compilation.
3/ Includes nonbattery scrap data only.
4/ Artificial graphite includes large amounts of materials made from petroleum coke.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	2,970,000	5,890,000	2,810,000	4,790,000
Manufactures	do.	88,000	273,000	136,000	361,000
Antimony:					
Metal	do.	16,900	60,900	18,300	50,900
Ore and concentrate, antimony content	do.	4,260	18,300	1,000	2,880
Oxides, antimony content	do.	15,400	51,800	18,300	54,200
Arsenic:					
Acid	do.	(2/)	3	1	14
Metal	do.	557	4,100	252	3,790
Trioxide	do.	29,000	15,200 r/	28,000	13,400
Bauxite and alumina:					
Alumina, calcined equivalent		4,000	908,000	4,330	1,020,000
Bauxite:					
Calcined		482	31,900	352	28,100
Crude and dried		10,100	235,000	10,200	267,000
Beryllium, metal and compounds	kilograms	135,000	3,820	78,900	2,540
Bismuth, metallic	do.	1,450,000	10,400	1,490,000	11,500
Cadmium:					
Metal	do.	848,000	2,710	843,000	2,400
Sulfide	do.	57,600	226	13,600	156
Chromium:					
Chemicals	metric tons	18,200	32,200 r/	14,700	28,900
Chromite ore	do.	253,000	20,100	250,000	23,200
Ferrochromium, metals, and alloys	do.	552,000	477,000	478,000	384,000
Pigments and preparations based on chromium	do.	6,310	16,000 r/	9,920	27,100
Cobalt:					
Metal:					
Alloys, articles, matte, wrought, and waste and scrap	do.	1,130	27,500	804	27,000
Unwrought	do.	5,530	325,000	5,760	327,000
Oxide and hydroxides	do.	808	34,300	824	36,200
Other forms	do.	1,170	15,800	1,270	14,700
Columbium (niobium) and tantalum:					
Columbium:					
Ferrocolumbium	do.	5,510	45,000	4,570	42,100
Ores and concentrates	do.	1,040	6,580	224	1,700
Oxide	do.	1,320	20,200	901	16,300
Unwrought, alloys, metals, and powder	do.	257	5,380	322	8,310
Tantalum:					
Ores and concentrates, includes synthetic	do.	1,120	24,300	1,160	27,500
Unwrought, alloys, metal, powders, and waste and scrap	do.	540	59,700	471	63,500
Wrought	do.	5	1,500	11	2,820
Copper:					
Scrap, alloyed and unalloyed	do.	157,000 r/	400,000 r/	178,000	341,000
Semimanufactures	do.	115,000	428,000	138,000	439,000
Unmanufactured, does not include unalloyed scrap, copper content	do.	653,000	1,680,000	782,000	1,800,000
Ferroalloys not listed elsewhere:					
Ferrophosphorus		7,590	3,860	10,600	5,920
Ferrotitanium and ferrosilicon-titanium		5,570	14,100	7,720	17,100
Ferrozirconium		46	110	212	413
Ferroalloys, other		30,800	40,300	33,900	5,300
Gallium, unwrought, waste and scrap	kilograms	18,100	4,350	30,000	9,440
Germanium materials, gross weight	do.	16,200	10,300	27,500	30,800
Gold:					
Bullion, refined	do.	111,000	1,360,000	143,000	1,780,000
Doré and precipitates	do.	9,820	92,600	11,900	117,000
Ore and concentrates	do.	5,020	53,900	3,460	42,200
Waste and scrap	do.	14,400	123,000	13,000	102,000
Indium, unwrought and waste and scrap	do.	85,200	32,900	33,200	12,100
Iron ore		17,600 r/	491,000 r/	18,400	556,000

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals--Continued:					
Iron and steel:					
Cast iron and steel products		319 r/	323,000	344	361,000
Direct-reduced iron		1,190	145,000	1,050	136,000
Fabricated steel products		2,600	4,400,000	2,680	4,500,000
Stainless steel	metric tons	741,000	(3/)	791,000	2,090,000
Steel mill products		22,100	11,700,000	26,500	12,700,000
Iron and steel scrap:					
Ferrous, includes tinplate and ternplate, excludes used rails for rerolling, other uses, ships, boats, and other vessels for scrapping		2,090	284,000	2,600	342,000
Pig iron, all grades		2,360	391,000	2,520	390,000
Direct-reduced iron, steelmaking grade		1,190	145,000	1,050	136,000
Ships, boats, and other vessels for scrapping		(2/)	2,010	(2/)	90
Used rails for rerolling and other uses, includes mixed (new plus used), rails		186	31,400	248	43,400
Lead, lead content:					
Base bullion		31	27	5	2
Ore and concentrates		2,600	1,960	6,570	2,500
Pigments and compounds, gross weight		37,000	42,000	43,800	56,600
Pigs and bars		264,000	176,000	268,000	214,000
Scrap, reclaimed, includes ash and residues		75	36	192	104
Wrought lead, all forms, including wire and powders, gross weight		6,600	13,700	10,000	16,500
Magnesium:					
Alloys, magnesium content	metric tons	15,900	55,100	24,600	89,700
Metal	do.	6,480	23,000	17,300	58,500
Powder, sheets, tubing, ribbons, wire, and other forms, gross weight	do.	867	4,410	1,280	6,470
Waste and scrap	do.	11,500	26,000	3,340	7,660
Manganese, manganese content:					
Chemicals, manganese dioxide and potassium permanganate, gross weight	do.	28,700	41,200	30,400	44,200
Metal, unwrought, waste and scrap, and other, gross weight	do.	10,800	18,000	11,300	19,700
Ore and concentrates with 20% or manganese, all grades	do.	187,000	33,300	231,000	42,400
Ferromanganese, all grades	do.	242,000	150,000	293,000	206,000
Silicomanganese	do.	201,000	161,000	213,000	188,000
Mercury and mercury-bearing waste and scrap	do.	377	1,190	340	1,800
Molybdenum, molybdenum content:					
Ferromolybdenum	do.	4,190	73,700	4,960	54,300
Molybdates, all, gross weight	do.	399 r/	3,090 r/	748	5,720
Ore and concentrates, roasted and other	do.	5,570	81,000	5,480	41,100
Oxides and hydroxides, gross weight	do.	918	11,200	1,160	8,670
Powders	do.	146	5,470	110	3,360
Unwrought	do.	102	3,430	84	2,360
Wire, gross weight	do.	1 r/	272 r/	2	309
Other, orange, mixtures of inorganic compounds, waste and scrap, and other, gross weight	do.	1,130 r/	9,580 r/	2,540	16,400
Nickel, nickel content:					
Alloyed, gross weight		9,140 r/	123,000 r/	10,200	134,000
Unwrought:					
Primary		149,000	1,240,000	142,000	1,190,000
Secondary		7,930	80,900	8,060	63,800
Wrought		2,310 r/	28,400 r/	636	14,100
Platinum-group metals	kilograms	221,000	1,770,000 r/	256,000	1,770,000
Rare-earths, rare-earth oxide content:					
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, and oxalates	do.	4,090,000	25,400	4,760,000	30,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent	do.	30,800	988	42,200	1,030
Rare-earth compounds, including oxides, hydroxides, nitrates, and other compounds except chlorides	do.	8,670,000	56,900	15,300,000	67,600
Mixtures of rare-earth oxide except cerium oxide	do.	678,000	16,700	879,000	21,900
Rare-earth metals, whether intermixed or alloyed	do.	754,000	7,670	357,000	3,710
Mixtures of rare-earth chlorides, except cerium chloride	do.	2,720,000	12,400	2,330,000	12,400

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals--Continued:					
Rare-earths, rare-earth oxide content--Continued:					
Ferrocerium and other pyrophoric alloys	kilograms	88,300	1,440	120,000	1,980
Rhenium:					
Ammonium perrhenate	do.	3,280	1,230	10,000	3,440
Metal	do.	9,550	7,050	10,800	9,500
Selenium and tellurium:					
Selenium, selenium content:					
Unwrought, and waste and scrap	do.	311,000	6,050	412,000	5,500
Selenium dioxide	do.	12,800	181	21,800	330
Tellurium, unwrought, and waste and scrap, gross weight	do.	45,800	2,430	73,700	3,190
Silicon:					
Ferrosilicon	metric tons	219,000	164,000	209,000	185,000
Metal	do.	95,900	178,000	81,800	214,000
Silver, contained silver:					
Ore and concentrates	kilograms	225,000	37,400	153,000	25,500
Doré and precipitates	do.	395,000	124,000	281,000	96,300
Bullion, refined	do.	2,630,000	428,000	2,580,000	441,000
Waste and scrap	do.	2,140,000	55,000	1,810,000	52,500
Thallium, unwrought, waste and scrap, powders	do.	1,180	90	166	23
Thorium:					
Compounds	do.	20,500	942	26,400	1,440
Ore, monazite concentrate	do.	40,000 r/	11	101,000	41
Tin:					
Compounds	metric tons	986	7,270	354	3,120
Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.	do.	24,800	58,900	16,000	58,800
Metal, unwrought	do.	33,200	204,000	30,200	187,000
Miscellaneous, includes tinfoil, tin powder, flitters, metallics, manufactures, n.s.p.f.	do.	XX	5,050	XX	5,070
Tinplate and terneplate	do.	272,000	180,000	251,000	161,000
Tinplate scrap	do.	16,000	2,390	64,600	5,690
Titanium:					
Concentrates:					
Ilmenite	do.	473,000	34,000	518,000	34,600
Titanium slag	do.	388,000	132,000	421,000	149,000
Rutile, natural and synthetic	do.	319,000 r/	131,000 r/	324,000	119,000
Titaniferous iron ore	do.	88,400	5,200	90,200	7,920
Pigments, dioxides and oxides	do.	183,000	323,000	167,000	290,000
Metal:					
Unwrought:					
Sponge	do.	7,560	35,200	10,100	70,800
Waste and scrap	do.	11,100	43,500	16,400	82,100
Ingots and billets	do.	1,880	19,100	2,590	34,800
Powder	do.	238	1,720	240	3,180
Other, includes blooms, sheet, bars, slabs, and other unwrought	do.	941	4,070	355	3,790
Wrought products and castings, bars, castings, foil, pipes, plates, profiles, rods, sheet, strip, tubes, wire, and other	do.	2,310 r/	44,700 r/	6,140	95,300
Tungsten, tungsten content:					
Ore and concentrate	do.	4,660 r/	25,200 r/	4,190	21,500
Ammonium paratungstate	do.	1,290	11,200	1,580	10,600
Ferrotungsten	do.	652	3,470	535	3,410
Miscellaneous tungsten-bearing materials, waste and scrap, unwrought metal (except alloys) in lumps, grains and powders, unwrought metal ingots, shot, alloy and other, wrought tungsten wire, plates, sheet, strip, foil and other, calcium tungstate, tungsten oxides, other metal-bearing materials in chief value of tungsten, chlorides of tungsten, sodium tungstate, and tungsten carbide	do.	6,150 r/	73,800	5,460	69,100
Vanadium:					
Aluminum-vanadium master alloy	kilograms	36,300 r/	342 r/	1,610	16,500
Ferrovanadium, vanadium content	do.	1,950,000	30,000	1,880,000	28,300
Pentoxide, anhydride, vanadium content	do.	547,000	7,040	485,000	6,150
Other oxides and hydroxides of vanadium, vanadium content	do.	35,600	608	10,800	205

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Metals--Continued:					
Vanadium--Continued:					
Metal, including waste and scrap	kilograms	796,000	14,200	96,100	811
Vanadium-bearing materials, ash and residues, and slag from the manufacture of iron and steel, vanadium pentoxide content	do.	4,520,000 r/	11,800 r/	4,060,000	9,480
Miscellaneous chemicals, sulfates, vanadates, hydrides, and nitrides, vanadium content	do.	47,000	444	332,000	5,280
Zinc:					
Compounds, lithopone, chlorides, compounds n.s.p.f., oxide, sulfate, and sulfide	metric tons	58,500	62,300	65,600	69,000
Ore and concentrates, zinc content	do.	10,300	4,380	15,100	6,380
Refined slab	do.	856,000	903,000	827,000	882,000
Rolled	do.	332	384	16,900	18,200
Zirconium and hafnium:					
Hafnium, unwrought, and waste and scrap	do.	5	1,130	8	1,580
Zirconium, ore and concentrates	do.	93,600	25,400	92,500	36,200
Zirconium, oxide includes germanium oxides and zirconium oxides.	do.	4,370	25,700	5,240	48,300
Zirconium, unwrought and waste and scrap	do.	735 r/	44,600 r/	619	37,800
Total		XX	38,600,000 r/	XX	41,800,000
Industrial minerals:					
Abrasives, manufactured:					
Fused aluminum oxide	metric tons	213,000	83,900	130,000	72,700
Silicon carbide	do.	172,000	75,300	181,000	94,000
Metallic abrasives	do.	25,600	14,500	20,200	12,200
Asbestos, unmanufactured	do.	21,900	4,810	21,600	4,880
Barite:					
Barium chemicals	do.	43,400	35,200	41,200	34,800
Crude and ground	do.	1,040,000	52,500	1,540,000	81,900
Boron, contained boric oxide:					
Borax		9	936	NA	NA
Boric acid		16	10,100	18	10,800
Colemanite		45	8,600	NA	NA
Ulexite		153	39,300	NA	NA
Bromine:					
Compounds, contained bromine	metric tons	7,520 r/	7,360 r/	15,300	29,300
Elemental	do.	2,220	1,460	415	305
Cement: Hydraulic and clinker		13,800	541,000	14,200	592,000
Clays:					
Artifically activated clay and activated earth	metric tons	15,200	8,360	18,600	11,000
Bentonite	do.	3,110	962	7,510	1,760
Chamotte or dina's earth	do.	1	4	39	37
China clay or kaolin	do.	12,000	3,900	13,700	5,840
Common blue clay and other ball clay	do.	1,370	338	1,400	337
Decolorizing earths and fuller's earth	do.	100	45	368	159
Fire clay	do.	1,350	831	355	230
Other clay	do.	1,870	1,580	2,520	1,600
Diamond, industrial:					
Industrial diamond stones	thousand carats	4,100	27,200	2,860	21,500
Powder, dust and grit	do.	188,000	81,500	218,000	98,900
Diatomite	metric tons	259	281	1,550	1,680
Feldspar and nepheline syenite:					
Feldspar	do.	8,980	813	7,150	594
Nepheline syenite	do.	316,000	19,700	247,000	20,900
Fluorspar:					
Aluminum fluoride	do.	22,200	17,200	18,300	16,800
Cryolite	do.	7,270	5,330	6,400	6,510
Fluorspar	do.	558,000	67,400	513,000	70,900
Hydrofluoric acid	do.	70,300	65,900	82,300	78,800
Garnet, industrial	do.	5,000 e/	XX	8,000 e/	XX
Gems and gemstones		XX	6,660,000	XX	7,240,000

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Industrial minerals--Continued:					
Graphite:					
Natural	metric tons	60,700	30,100	53,400	28,600
Electric furnace electrodes	do.	47,500	102,000	59,300	135,000
Gypsum:					
Boards		560	64,400	748	89,300
Crude		8,160	60,000	8,050	62,500
Plasters		8	1,520	11	2,220
Other		XX	40,300	XX	42,400
Iodine, crude and potassium iodide	metric tons	3,950	39,100	4,860	62,300
Iron oxide pigments, selected:					
Natural	do.	6,800 r/	2,650	9,390	3,370
Synthetic	do.	52,500	75,000	53,200	70,600
Kyanite and related materials, andalucite	do.	3,210	623	11,300	2,310
Lime		289	20,200	262	19,400
Lithium chemicals:					
Carbonate	metric tons	5,970	16,900	4,590	12,500
Hydroxide	do.	104	593	126	1,440
Magnesium compounds:					
Compounds, chlorides, hydroxide, peroxide, and sulfates	do.	64,900	19,200	64,700	18,600
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	139,000	21,200	114,000	19,200
Dead-burned and fused magnesia	do.	393,000	73,200	271,000	57,600
Magnesite, crude	do.	13,600	4,320	9,190	1,900
Other magnesia	do.	12,600	9,930	11,900	9,040
Mica:					
Scrap and flake:					
Powder	do.	14,200	9,280	13,600	8,250
Waste	do.	7,730	1,880	4,840	1,230
Sheet:					
Unworked	do.	3,080	1,950	5,240	2,310
Worked	do.	1,150	10,700	1,090	10,800
Nitrogen, major compounds		8,010	1,610,000	8,170 p/	1,680,000 p/
Peat moss, poultry and fertilizer grade		669,000	121,000	667,000	116,000
Perlite	metric tons	84,000	2,350	125,000	3,530
Phosphate rock and phosphatic materials		777 r/	62,300 r/	841	87,300
Potash:					
Potassium chloride	metric tons	7,830,000	577,000	8,030,000	539,000
Potassium sulfate	do.	51,800	9,530	60,400	11,300
Potassium nitrate	do.	36,600	9,170	30,400	8,690
Potassium sodium nitrate mixtures	do.	38,600	6,180	21,900	3,430
Pumice:					
Crude or unmanufactured		237	16,400	215	16,000
Wholly or partially manufactured		1	329	(2/)	708
Salt		7,090	114,000	10,600	167,000
Sand and gravel:					
Construction		1,120	12,000	1,260	15,800
Industrial		59 r/	2,730	7	1,500
Silica:					
Quartz crystal, cultured electronic- and optical-grade	metric tons	47	10,800	42	9,480
Tripoli and special silica, special silica stone products	do.	XX	2,900	XX	2,960
Soda ash		83	12,000	107	14,700
Sodium sulfate		143 r/	11,800 r/	90	8,660
Stone:					
Crushed stone and calcium carbonate fines		10,900	91,900	11,300	91,800
Dimension		NA	478,000	NA	462,000
Strontium:					
Compounds, carbonate and nitrate	metric tons	35,100	21,400	34,400	21,200
Sulfate, celestite	do.	28,900	2,060	26,400	1,770
Sulfur:					
Elemental		2,510	143,000	1,620	60,500
Sulfuric acid, 100% H_2SO_4	metric tons	1,920,000	92,900 r/	2,070,000	78,000

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		1995 Quantity	1995 Value	1996 Quantity	1996 Value
Industrial minerals--Continued:					
Talc, unmanufactured	metric tons	146,000	14,800	187,000	20,500
Vermiculite		30	3,900 e/	48	6,240 e/
Wollastonite		NA	NA	1,380	276 e/
Total		XX	11,900,000	XX	12,600,000
Grand total		XX	50,400,000 r/	XX	54,400,000

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Data not available at time of table compilation.

TABLE 9
COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES 1/

(Metric tons unless otherwise specified)

Mineral		1995 World r/	1995 U.S.	1995 U.S. percent of World	1996 World e/	1996 U.S.	1996 U.S. percent of World
Metals, mine basis:							
Antimony 2/		154,000	W	NA	126,000	W	NA
Arsenic trioxide		48,200	--	--	42,100	--	--
Bauxite 3/	thousand tons	107,000	W	NA	114,000	W	NA
Beryl 4/		6,860	5,040	73 r/	7,020	5,260 5/	75
Chromite	thousand tons	14,300	--	--	12,200	--	--
Cobalt 2/ 4/		23,800	--	--	27,000	--	--
Columbium-tantalum concentrate, gross weight 4/		43,400	--	--	38,600	--	--
Copper 2/	thousand tons	10,100	1,310	13	11,000	1,340 5/	12
Gold 2/	kilograms	2,220,000	317,000 r/	14	2,250,000	318,000	14
Iron ore, gross weight	thousand tons	1,030,000	62,500	6	1,020,000	62,100 5/	6
Lead 2/	do.	2,780	394	14 r/	2,920	436	15
Manganese ore, gross weight	do.	23,000	--	--	22,300	--	--
Mercury		3,160	W	NA	2,890	W	NA
Molybdenum 2/		141,000	60,900	43 r/	128,000	54,900 5/	43
Nickel 2/		1,030,000	1,560 e/	(6/) e/	1,080,000	1,330 5/	(6/)
Platinum-group metals	kilograms	287,000	6,840	2	284,000	7,940	3
Silver 2/		15,200	1,640	11	15,200	1,520 5/	10
Tin 2/		195,000	--	--	196,000	--	--
Titanium concentrates, gross weight:							
Ilmenite, including leucoxene	thousand tons	3,970	W	NA	3,990	W	NA
Rutile	do.	416	W	NA	415	W	NA
Tungsten 2/		38,500	W	NA	31,900	W	NA
Vanadium 2/		37,700	1,990	5 r/	39,100	3,730 5/	10
Zinc 2/	thousand tons	7,240	644	9	7,440	628 5/	8
Metals, refinery basis:							
Aluminum	do.	19,900	3,380	17	20,700	3,580 5/	17
Bismuth		4,260	W	NA	4,230	W	NA
Cadmium		18,900	1,270	7	18,900	1,530 p/ 5/	8
Cobalt		22,100	--	--	25,400	--	--
Copper, primary and secondary	thousand tons	11,900	2,280 r/	19	12,500	2,340	19
Lead, primary and secondary 7/	do.	5,590	1,390 r/	25	5,480	1,430	26
Magnesium, primary		389,000	142,000	37 r/	341,000	133,000	39
Nickel 8/		908,000	8,290	1	917,000	15,100 5/	2
Selenium 9/	kilograms	2,070,000	373,000	18	2,150,000	379,000 5/	18
Tellurium	do.	173,000	W	NA	129,000	W	NA
Tin, smelter 10/		220,000	11,600	5	207,000	11,000 5/	5
Zinc, smelter, primary and secondary		7,550,000	363,000	5	7,530,000	366,000 5/	5
Iron and steel:							
Direct-reduced iron	thousand tons	30,500	460	2	31,700	450 5/	1
Iron, pig	do.	532,000	50,900	10	528,000	49,400 5/	9
Steel, raw	do.	754,000	95,200	13	758,000	94,700 5/	13

See footnotes at end of table.

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TABLE 9--Continued
COMPARISON OF WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES 1/

(Metric tons unless otherwise specified)

Mineral		1995 World r/	1995 U.S.	1995 U.S. percent of World	1996 World e/	1996 U.S.	1996 U.S. percent of World
Industrial minerals:							
Asbestos	thousand tons	2,420	9	(6/)	2,290	10	(6/)
Barite	do.	4,300	543 11/	13 r/	4,460	662 5/ 11/	15
Boron minerals	do.	2,890	1,190 r/ 11/	41 r/	2,980	1,150 5/ 11/	39
Bromine		429,000 e/	218,000 11/	51 r/ e/	451,000	227,000 5/ 11/	50
Celestite 4/		291,000	--	--	297,000	--	--
Cement, hydraulic	thousand tons	1,440,000	78,300 12/	5 r/	1,480,000	80,800 5/ 12/	5
Clays:							
Bentonite 4/	do.	9,530	3,820	40 r/	9,190	3,740 5/	41
Fuller's earth	do.	3,690	2,640 11/	72 r/	3,660	2,600 5/	71
Kaolin 4/	do.	38,500	9,480 r/ 11/	25 r/	38,600	9,120 5/	24
Diamond, natural	thousand carats	113,000 e/	--	-- e/	117,000	--	--
Diatomite	thousand tons	1,410	687 e/ 11/	49 r/ e/	1,410	698 11/	49
Feldspar	do.	6,780	880	13 r/	6,750	890 5/	13
Fluorspar	do.	4,050	51 13/	1	4,140	8 13/	(6/)
Graphite, natural		741,000	--	--	644,000	--	--
Gypsum	thousand tons	96,500	16,600	17	99,700	17,500 5/	18
Iodine, crude		12,900	1,220 r/	9	13,100	1,270 5/	10
Lime 12/	thousand tons	121,000	18,500 11/	15 r/	121,000	19,100 5/ 11/	16
Magnesite, crude	thousand tons	9,940	W	NA	9,170	W	NA
Mica, including scrap and flake 14/		253,000	108,000	43 r/	225,000	96,600 5/	43
Nitrogen: N content of ammonia	thousand tons	96,100	13,000 r/ 15/	14 r/	97,500	14,600 5/ 15/	15
Peat 16/	do.	24,300	588	2 r/	25,800	549 5/	2
Perlite 4/		1,710,000	700,000 11/	41 r/	1,680,000	684,000 11/	41
Phosphate rock, gross weight	thousand tons	130,000	43,500	33	141,000	45,400	32
Potash, K_2O equivalent	do.	24,700	1,480	6	23,900	1,390	6
Pumice 17/	do.	11,000	529 11/	5	11,100	612 5/ 11/	6
Salt 12/	do.	192,000	42,200 e/	22 e/	192,000	42,300	22
Sand and gravel, industrial, silica 4/	do.	119,000	28,200 r/ 11/	24	117,000	27,800 5/ 11/	24
Sodium compounds, n.e.s., natural and manufactured:							
Soda ash 18/	do.	30,300	10,100	33	30,400	10,200 5/	34
Sulfate	do.	4,870	645 r/	13 r/	4,870	551 5/	11
Sulfur, all forms	do.	53,200	11,800 r/	22	52,400	12,000	23
Talc and pyrophyllite 19/	do.	8,400	1,060 r/	13 r/	8,190	994 5/	12
Vermiculite		482,000	171,000 11/	36 r/	266,000	W	NA

e/ Estimated. p/ Preliminary. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits.

2/ Content of ore and concentrate.

3/ U.S. figures represent dried bauxite equivalent of crude ore; to the extent possible, individual country figures that are included in the world total are also on the dried bauxite basis, but for some countries available data are insufficent to permit this adjustment.

4/ World total does not include an estimate for output in China.

5/ Reported figure.

6/ Less than 1/2 unit.

7/ Includes bullion.

8/ Refined nickel plus nickel content of ferronickel, nickel oxide, and other nickel salts.

9/ U.S. production includes semirefined selenium exported for further refining.

10/ Includes tin content of alloys made directly from ore.

11/ Quantity sold or used by producers.

12/ Includes Puerto Rico data. Portland and masonary cement only.

13/ Shipments.

14/ Excludes U.S. production of low-quality sericite and sheet mica, if any.

15/ Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

16/ Data for the United States exclude proprietary amounts of fuel peat.

17/ World total does not include estimates for output in Japan, Mexico, the former U.S.S.R, and Zaire.

18/ U.S. production is natural only.

19/ Data for the United States exclude proprietary pyrophyllite production.

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MINING AND QUARRYING TRENDS

By Jean K. Moore

The mining and quarrying trends shown in this report were calculated from data reported to the U.S. Geological Survey (USGS) by nonfuel mining and quarrying companies operating in the United States. The data for 1996 were reported on the Mine, Development, and Mineral Exploration Supplement, a statistical survey conducted by the USGS. Additional data for 1996 were derived from 58 annual USGS production and consumption surveys of minerals producers. These surveys covered 59 nonfuel mineral commodities produced in the United States.

Mining and quarrying data for 1996, as shown in this report, include the annual data for both the construction sand and gravel commodities and the data for the commodities of crushed and dimension stone. Prior to 1994, these mineral commodities were surveyed biennially and appeared alternately in this report. The inclusion of both sets of these data in this report results in essentially a complete coverage of nonfuel mineral production in the United States. However, this does not make comparisons of 1994-96 data with previously reported annual data possible.

Total domestic mining of nonfuel mineral materials amounted to 5.6 billion metric tons in 1996, a 4% increase above that of 1995. These materials included 3.5 billion tons of crude ore mined or quarried and 2.1 billion tons of mine waste and ore from development. Of the nonfuel mineral materials mined, 53% was for the production of industrial minerals and 47% was for the production of metals. Overall, 97% of nonfuel mineral mining and quarrying was performed at surface levels and the remaining 3% was underground.

Total surface mining and quarrying for industrial minerals amounted to 2.9 billion tons, a slight increase above that of 1995. Crude ore mined at these surface operations was 2.4 billion tons, and the remaining 434 million tons was waste and ore from development. Underground mining for industrial minerals amounted to only 111 million tons, of which 98% was crude ore.

Total surface mining for metal ores came to 2.6 billion tons, a 6% increase compared with that of 1995. Of the 2.6 billion tons, about 950 million tons was crude ore mined and the remaining 1.7 billion tons was waste and ore from development. Underground mining of metal ores was small, amounting to only 51 million tons, of which 94% was crude ore.

The major States in which mining for nonfuel minerals occurred were, in order of total material handled, Nevada, Arizona, Florida, Minnesota, California, Michigan, Texas, Utah, New Mexico, and Ohio. These 10 States accounted for more than 60% of the mining conducted in the United States. Virtually all of the mining in these States was surface mining.

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TABLE 1
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES, 1/ BY TYPE

(Million metric tons)

Type and year	Surface 2/			Underground 3/			All mines		
	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total
Metals:									
1992	921	1,110	2,030	36	2	38	957	1,110	2,070
1993	921	1,140	2,060	34	2	36	955	1,140	2,100
1994	901	1,520 r/	2,420 r/	37	1	38	938	1,520 r/	2,460 r/
1995	922 r/	1,560 r/	2,480 r/	53 r/	2	55 r/	975 r/	1,560 r/	2,540
1996	949	1,670	2,620	48	3	51	997	1,680	2,670
Industrial minerals:									
1992 5/	991 r/	267	1,260	42 r/	(6/)	42 r/	1,030	267	1,300
1993	1,180	310	1,490	101 r/	(6/)	101 r/	1,280	311	1,590
1994	2,270 r/	425	2,690 r/	104 r/	(6/)	104 r/	2,370	425	2,800
1995	2,350	455	2,800 r/	104 r/	3	106 r/	2,450	458	2,910
1996	2,430	434	2,860	108	3	111	2,530	437	2,970
All mineral commodities:									
1992	1,910 r/	1,380	3,290	78 r/	2	80 r/	1,990	1,380	3,370
1993	2,100	1,450	3,550	135 r/	2	137 r/	2,230	1,450	3,680
1994	3,170 r/	1,950 r/	5,120 r/	141 r/	1	142 r/	3,310	1,950 r/	5,260 r/
1995	3,270	2,020	5,280 r/	156 r/	5	161 r/	3,420	2,020	5,450
1996	3,370	2,110	5,480	157	6	162	3,530	2,110	5,640

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes materials from wells, ponds, and pumping operations.

3/ Includes solution mining.

4/ Includes ore and waste from development operations.

5/ Crushed and broken and dimension stone data were not available because of biennial canvassing.

6/ Less than 1/2 unit.

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TABLE 2
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1996, BY COMMODITY AND STATE 1/

(Thousand metric tons)

	Surface 2/			Underground 3/			All mines		
	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total
Metal ores:									
Copper	419,000	447,000	866,000	W	W	W	419,000	447,000	866,000
Gold	291,000	1,000,000	1,290,000	4,260	760	5,020	295,000	1,000,000	1,300,000
Iron	206,000	170,000	377,000	W	W	W	206,000	170,000	377,000
Platinum and palladium	--	--	--	385	330	715	385	330	715
Zinc	W	W	W	5,720	1,030	6,750	5,720	1,030	6,750
Other 5/	32,500	56,100	88,600	38,000	755	38,800	70,600	56,800	127,000
Total	949,000	1,670,000	2,620,000	48,400	2,870	51,300	997,000	1,680,000	2,670,000
Industrial minerals:									
Barite	1,270	714	1,980	--	--	--	1,270	714	1,980
Clays	40,000	34,800	74,800	W	W	W	40,000	34,800	74,800
Diatomite	1,310	W	1,310	--	--	--	1,310	W	1,310
Feldspar 6/	850	W	850	--	--	--	850	W	850
Garnet	55	--	55	--	--	--	55	--	55
Gypsum	14,300	6,150	20,500	2,710	--	2,710	17,000	6,150	23,200
Mica (scrap)	262	140	402	--	--	--	262	140	402
Perlite	W	W	W	2	--	2	2	--	2
Phosphate rock	174,000	W	174,000	--	--	--	174,000	W	174,000
Potash	W	--	W	13,100	--	13,100	13,100	--	13,100
Pumice 7/	569	W	569	--	--	--	569	W	569
Salt	4,930	--	4,930	32,700	W	32,700	37,700	W	37,700
Sand and gravel:									
Construction	894,000	W	894,000	W	--	W	894,000	W	894,000
Industrial	25,000	W	25,000	--	--	--	25,000	W	25,000
Soda ash	W	--	W	10,200	--	10,200	10,200	--	10,200
Stone:									
Crushed	1,250,000	103,000	1,360,000	48,400	334	48,800	1,300,000	103,000	1,410,000
Dimension	1,480	586	2,070	50	--	50	1,530	586	2,120
Talc and pyrophyllite	802	1,770	2,570	W	--	W	802	1,770	2,570
Other 8/	12,600	287,000	300,000	1,020	2,310	3,320	13,600	289,000	303,000
Total	2,430,000	434,000	2,860,000	108,000	2,640	111,000	2,530,000	437,000	2,970,000
Grand total	3,370,000	2,110,000	5,480,000	157,000	5,510	162,000	3,530,000	2,110,000	5,640,000
States:									
Alabama	55,900	5,520	61,400	W	--	W	55,900	5,520	61,400
Alaska	22,600	W	22,600	W	W	W	22,600	W	22,600
Arizona	375,000	W	375,000	W	W	W	375,000	W	375,000
Arkansas	39,800	6,560	46,300	--	--	--	39,800	6,560	46,300
California	197,000	68,500	265,000	W	W	W	197,000	68,500	265,000
Colorado	51,500	W	51,500	6,120	W	6,120	57,600	W	57,600
Connecticut	13,100	597	13,700	--	--	--	13,100	597	13,700
Delaware	2,370	--	2,370	--	--	--	2,370	--	2,370
Florida	255,000	264,000	519,000	351	3	354	255,000	264,000	520,000
Georgia	81,500	14,900	96,400	W	W	W	81,500	14,900	96,400
Hawaii	6,950	525	7,470	--	--	--	6,950	525	7,470
Idaho	50,700	43,800	94,500	368	W	368	51,100	43,800	94,900
Illinois	99,800	5,300	105,000	4,290	30	4,320	104,000	5,330	109,000
Indiana	74,200	5,290	79,500	4,600	W	4,600	78,800	5,290	84,100
Iowa	40,900	2,550	43,500	6,840	37	6,870	47,800	2,590	50,300
Kansas	33,800	2,200	36,000	3,580	7	3,580	37,400	2,210	39,600
Kentucky	52,100	4,340	56,500	12,800	90	12,900	64,900	4,430	69,400
Louisiana	15,900	515	16,500	15,300	W	15,300	31,300	515	31,800
Maine	9,140	243	9,390	--	--	--	9,140	243	9,390
Maryland	34,600	2,240	36,800	W	W	W	34,600	2,240	36,800
Massachusetts	24,200	924	25,200	W	W	W	24,200	924	25,200
Michigan	143,000	70,900	213,000	829	--	829	143,000	70,900	214,000
Minnesota	205,000	104,000	310,000	--	--	--	205,000	104,000	310,000
Mississippi	16,500	1,160	17,700	--	--	--	16,500	1,160	17,700
Missouri	73,300	6,280	79,600	11,800	W	11,800	85,200	6,280	91,500
Montana	35,100	W	35,100	791	W	791	35,900	W	35,900

See footnotes at end of table.

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TABLE 2--Continued
MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1996, BY COMMODITY AND STATE 1/

(Thousand metric tons)

	Surface 2/			Underground 3/			All mines		
	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total	Crude ore	Waste 4/	Total
States--Continued:									
Nebraska	17,400	599	18,000	W	W	W	17,400	599	18,000
Nevada	239,000	835,000	1,070,000	2,110	715	2,830	241,000	835,000	1,080,000
New Hampshire	9,030	134	9,160	--	--	--	9,030	134	9,160
New Jersey	33,000	1,540	34,600	--	--	--	33,000	1,540	34,600
New Mexico	36,800	W	36,800	14,200	W	14,200	50,900	W	50,900
New York	71,700	5,310	77,100	4,600	W	4,600	76,300	5,310	81,700
North Carolina	81,600	10,200	91,700	--	--	--	81,600	10,200	91,700
North Dakota	8,200	W	8,200	--	--	--	8,200	W	8,200
Ohio	112,000	6,710	119,000	4,500	W	4,500	117,000	6,710	123,000
Oklahoma	40,200	2,940	43,100	W	W	W	40,200	2,940	43,100
Oregon	40,500	2,110	42,600	--	--	--	40,500	2,110	42,600
Pennsylvania	94,600	7,020	102,000	4,960	35	4,990	99,500	7,060	107,000
Rhode Island	3,440	108	3,550	--	--	--	3,440	108	3,550
South Carolina	40,300	7,360	47,700	--	--	--	40,300	7,360	47,700
South Dakota	21,100	24,200	45,300	W	--	W	21,100	24,200	45,300
Tennessee	60,100	5,140	65,300	8,820	W	8,820	68,900	5,140	74,100
Texas	153,000	9,960	163,000	10,100	W	10,100	163,000	9,960	173,000
Utah	90,400	W	90,400	W	W	W	90,400	W	90,400
Vermont	8,490	408	8,890	W	--	W	8,490	408	8,890
Virginia	69,400	5,420	74,800	W	W	W	69,400	5,420	74,800
Washington	51,600	1,360	53,000	W	--	W	51,600	1,360	53,000
West Virginia	14,700	1,170	15,900	2,900	15	2,910	17,600	1,180	18,800
Wisconsin	58,100	2,820	61,000	--	--	--	58,100	2,820	61,000
Wyoming	11,700	3,070	14,800	9,110	--	9,110	20,800	3,070	23,900
Undistributed 9/	--	564,000	564,000	27,700	4,580	32,300	27,700	569,000	597,000
Grand total	3,370,000	2,110,000	5,480,000	157,000	5,510	162,000	3,530,000	2,110,000	5,640,000

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes materials from wells, ponds, and pumping operations.

3/ Includes solution mining.

4/ Includes ore and waste from development operations.

5/ Includes beryllium concentrate, gold-silver ore, lead, magnesium metal, molybdenum, nickel, rare earth concentrates, silver, tin, titanium, uranium, and metal items indicated by symbol W.

6/ Includes aplite.

7/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

8/ Includes abrasives, boron minerals, bromine, emery, greensand marl, iodine, iron oxide pigments, kyanite, lithium minerals, magnesite, magnesium compounds, olivine, sodium sulfate, sulfur (Frasch), tripoli, vermiculite, wollastonite, zeolites, and industrial minerals indicated by symbol W.

9/ Includes State items indicated by symbol W.

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TABLE 3
VALUE OF PRINCIPAL MINERAL PRODUCTS AND BYPRODUCTS OF SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1996 1/

(Dollars per metric ton)

Commodity	Surface			Underground			All mines		
	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total
Metal ores:									
Copper	9.69	1.53	11.22	W	W	W	9.69	1.53	11.22
Gold	11.52	0.66	12.18	69.89	0.30	70.19	12.22	0.66	12.88
Iron	8.55	--	8.55	W	W	W	8.55	W	8.55
Average, metals 2/	10.55	1.13	11.68	30.88	3.66	34.54	11.53	1.25	12.78
Industrial minerals:									
Barite	11.83	--	11.83	W	--	W	11.83	--	11.83
Clays	42.06	W	42.06	W	--	W	42.06	W	42.06
Diatomite	117.19	--	117.19	--	--	--	117.19	--	117.19
Feldspar 3/	21.27	W	21.27	--	--	--	21.27	W	21.27
Gypsum	6.97	W	6.97	7.13	--	7.13	6.99	W	6.99
Magnesium compounds	89.26	W	89.26	--	--	--	89.26	W	89.26
Mica (scrap)	24.59	W	24.59	--	--	--	24.59	W	24.59
Phosphate rock	6.13	W	6.13	--	--	--	6.13	W	6.13
Potash	W	W	W	17.13	--	17.13	17.13	W	17.13
Pumice 4/	24.19	--	24.19	--	--	--	24.19	--	24.19
Salt	82.40	--	82.40	19.27	0.07	19.34	27.04	0.06	27.10
Sand and gravel:									
Construction	4.36	0.07	4.43	W	--	W	4.36	0.07	4.43
Industrial	17.67	0.75	18.42	--	--	--	17.67	0.75	18.42
Soda ash	W	W	W	89.84	W	89.84	89.84	W	89.84
Stone:									
Crushed	5.34	0.01	5.35	6.54	W	6.54	5.39	0.01	5.40
Dimension	150.49	1.66	152.15	174.95	--	174.95	151.28	1.60	152.89
Talc and pyrophyllite	30.86	W	30.86	W	--	W	30.86	W	30.86
Average, industrial minerals 2/	6.57	0.06	6.64	20.09	0.55	20.64	7.14	0.09	7.22
Average, industrial minerals 2/ (excluding sand and gravel and stone)	19.01	0.27	19.28	30.96	1.00	31.95	21.32	0.41	21.73
Average, metals and industrial minerals 2/	7.69	0.36	8.05	23.44	1.52	24.95	8.37	0.41	8.78
Average, metals and industrial minerals 2/ (excluding sand and gravel and stone)	12.29	0.95	13.24	30.92	2.19	33.11	13.82	1.05	14.87

W Withheld to avoid disclosing company proprietary data; included in appropriate "Average."

1/ Values calculated from unrounded data; may not add to totals shown because of independent rounding.

2/ Includes unpublished data for metals: beryllium concentrate, gold-silver ore, lead, magnesium metal, molybdenum, nickel, platinum and palladium, rare-earth metal concentrate, silver, titanium, and zinc, and industrial minerals: abrasives (silica stone), asbestos, boron minerals, bromine, emery, fluorspar, garnet, greensand marl, iodine, iron oxide pigments, kyanite, lithium minerals, magnesite, olivine, perlite, sodium sulfate, sulfur (Frasch), tripoli,vermiculite, wollastonite, and zeolites, and items indicated by symbol W.

3/ Includes aplite.

4/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

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TABLE 4
NUMBER OF DOMESTIC METAL AND INDUSTRIAL MINERAL MINES IN THE UNITED STATES IN 1996, BY COMMODITY AND STATE 1/ 2/

Commodity	Total number of mines	Less than 1,000 tons	1,000 to 10,000 tons	10,000 to 100,000 tons	100,000 to 1,000,000 tons	1,000,000 to 10,000,000 tons	More than 10,000,000 tons
Metal ores:							
Beryllium concentrate	1	--	--	--	1	--	--
Copper	27	1	--	1	4	10	11
Gold	88	1	4	5	20	53	5
Gold-silver	1	--	--	--	--	1	--
Iron	16	--	--	4	2	2	8
Lead	9	--	--	--	6	3	--
Magnesium metal	3	--	--	1	1	1	--
Molybdenum	3	--	--	--	1	2	--
Nickel	1	--	--	1	--	--	--
Platinum and palladium	1	--	--	--	1	--	--
Rare earth metal concentrates	1	--	--	--	1	--	--
Silver	3	--	--	1	1	1	--
Titanium	4	--	1	--	2	1	--
Uranium	9	7	2	--	--	--	--
Zinc	14	--	--	--	11	3	--
Total	181	9	7	13	51	77	24
Industrial minerals:							
Abrasives	9	9	--	--	--	--	--
Barite	9	--	2	3	4	--	--
Boron minerals	4	2	--	--	1	1	--
Bromine	6	--	--	6	--	--	--
Clays	703	30	130	441	102	--	--
Diatomite	12	1	--	8	3	--	--
Emery	1	1	--	--	--	--	--
Feldspar 3/	9	1	3	3	2	--	--
Garnet	4	--	1	3	--	--	--
Greensand marl	1	--	1	--	--	--	--
Gypsum	57	--	3	12	42	--	--
Iodine	4	4	--	--	--	--	--
Iron oxide pigments	7	6	--	1	--	--	--
Kyanite	2	--	--	--	2	--	--
Lithium minerals	3	1	--	1	1	--	--
Magnesite	1	--	--	--	1	--	--
Magnesium compounds	5	--	1	1	3	--	--
Mica (scrap)	8	--	5	1	2	--	--
Olivine	4	--	1	3	--	--	--
Perlite	8	--	4	1	3	--	--
Phosphate rock	19	--	--	--	1	8	10
Potash	9	--	--	3	--	6	--
Pumice 4/	15	2	4	7	2	--	--
Salt	68	--	5	10	42	11	--
Sand and gravel:							
Construction	7,540	145	1,770	3,550	1,960	112	--
Industrial	118	--	8	45	64	1	--
Sodium compounds:							
Soda ash	7	--	--	--	2	5	--
Sodium sulfate	2	--	--	--	2	--	--
Stone:							
Crushed	3,400	231	272	903	1,660	333	1
Dimension	217	56	126	33	2	--	--
Sulfur (Frasch)	2	--	--	--	1	1	--
Talc and pyrophyllite	18	3	2	9	4	--	--
Tripoli	5	1	1	3	--	--	--
Vermiculite	13	--	--	13	--	--	--
Wollastonite	3	--	--	2	1	--	--
Zeolites	6	2	2	2	--	--	--
Total	12,300	495	2,340	5,070	3,910	478	11
Grand total	12,500	504	2,350	5,080	3,960	555	35

See footnotes at end of table.

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TABLE 4--Continued
NUMBER OF DOMESTIC METAL AND INDUSTRIAL MINERAL MINES IN THE UNITED STATES IN 1996, BY COMMODITY AND STATE 1/ 2/

Commodity	Total number of mines	Less than 1,000 tons	1,000 to 10,000 tons	10,000 to 100,000 tons	100,000 to 1,000,000 tons	1,000,000 to 10,000,000 tons	More than 10,000,000 tons
States:							
Alabama	196	--	29	80	70	17	--
Alaska	189	12	5	162	7	3	--
Arizona	254	20	33	75	100	18	8
Arkansas	153	11	16	64	50	12	--
California	563	24	76	204	215	43	1
Colorado	355	9	76	182	76	12	--
Connecticut	89	--	11	45	32	1	--
Delaware	10	--	1	3	6	--	--
Florida	165	--	3	39	89	24	10
Georgia	271	3	29	117	97	25	--
Hawaii	30	--	5	11	13	1	--
Idaho	237	4	44	115	67	7	--
Illinois	297	2	24	95	152	24	--
Indiana	245	--	23	68	135	19	--
Iowa	367	3	33	224	101	6	--
Kansas	349	2	133	113	99	2	--
Kentucky	119	--	6	15	84	14	--
Louisiana	107	5	5	42	48	7	--
Maine	196	5	78	84	29	--	--
Maryland	89	5	11	24	37	12	--
Massachusetts	138	4	17	52	60	5	--
Michigan	476	3	86	216	151	18	2
Minnesota	555	2	74	381	85	7	6
Mississippi	105	--	10	52	41	2	--
Missouri	357	14	53	106	169	15	--
Montana	207	16	49	106	31	4	1
Nebraska	178	--	20	118	37	3	--
Nevada	508	6	349	56	54	39	4
New Hampshire	76	--	8	41	27	--	--
New Jersey	80	1	3	24	43	9	--
New Mexico	146	13	28	63	32	9	1
New York	599	25	147	253	164	10	--
North Carolina	267	10	42	101	96	17	1
North Dakota	150	6	20	105	18	1	--
Ohio	371	9	27	127	183	25	--
Oklahoma	155	6	15	61	65	8	--
Oregon	587	190	154	145	94	4	--
Pennsylvania	359	11	32	108	188	20	--
Rhode Island	22	--	2	7	13	--	--
South Carolina	150	--	17	75	50	8	--
South Dakota	264	7	99	127	26	5	--
Tennessee	201	4	12	58	109	18	--
Texas	481	27	25	162	237	30	--
Utah	195	2	37	80	65	10	1
Vermont	141	8	34	81	18	--	--
Virginia	190	10	18	45	99	18	--
Washington	384	8	55	194	122	5	--
West Virginia	67	2	1	23	37	4	--
Wisconsin	690	4	247	304	129	6	--
Wyoming	104	2	13	60	23	6	--
Grand total	12,500	504	2,350	5,080	3,960	555	35

1/ Based on crude ore mined.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes aplite.
4/ Excludes volcanic cinder and scoria; included with crushed stone.

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TABLE 5
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINING OPERATIONS
IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT OF CRUDE ORE

Type of ore and mining operation 1/	State	Operator	Commodity	Mining method
Metal ores:				
Morenci	Arizona	Phelps Dodge Corp.	Copper	Open pit.
Carlin Mines Complex	Nevada	Newmont Gold Co.	Gold	Open pit and stoping.
Bingham Canyon	Utah	Kennecott, Utah Copper Corp.	Copper	Open pit.
Minntac	Minnesota	USX	Iron	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	Gold	Do.
Sierrita	Arizona	Cyprus Climax Metals Co.	Copper	Do.
Hibbing	Minnesota	Cleveland-Cliffs, Inc.	Iron	Do.
Cyprus Miami (Inspiration)	Arizona	Cyprus Climax Metals Co.	Copper	Do.
Bagdad	do.	do.	do.	Do.
Empire	Michigan	Cleveland-Cliffs, Inc.	Iron	Do.
Hoyt Lakes	Minnesota	Cleveland-Cliffs, Inc.	do.	Do.
Pinto Valley	Arizona	BHP Copper Inc.	Copper	Do.
Mission Complex	do.	ASARCO Incorporated	do.	Open pit and stoping.
Twin Creeks	Nevada	Santa Fe Pacific Gold Corp.	Gold	Open pit.
Chino	New Mexico	Chino Mines Co.	Copper	Do.
San Manuel	Arizona	BHP Copper Inc.	do.	Stoping.
Ray Pit	do.	ASARCO Incorporated	do.	Open pit.
National Steel	Minnesota	National Steel Pellet Co.	Iron	Do.
Thunderbird	do.	EVTAC Mining	do.	Do.
Continental	Montana	Montana Resources Inc.	Copper	Do.
Mesquite	California	Santa Fe Pacific Gold Corp.	Gold	Do.
Florida Canyon	Nevada	Pegasus Gold Inc.	Gold	Do.
Tilden	Michigan	Cleveland-Cliffs, Inc.	Iron	Do.
Peter Mitchell	Minnesota	Northshore Mining Co.	do.	Do.
Robinson	Nevada	BHP Copper Inc.	Gold and copper	Do.
Industrial minerals:				
Florida mines (6)	Florida	IMC-Agrico Co.	Phosphate rock	Do.
Fort Meade	do.	Cargill Fertilizer Inc.	do.	Do.
F E C Quarry	do.	CSR America Inc.	Stone	Open quarry.
Aurora	North Carolina	PCS Phosphate	Phosphate rock	Open pit.
Reed Quarry	Kentucky	Vulcan Materials Co.	Stone	Open quarry.
Hardee	Florida	C F Industries Inc.	Phosphate rock	Open pit.
Beckmann	Texas	Redland Aggregates North America, Redland Stone Products Co.	Stone	Open quarry.
Calcite Operation	Michigan	Michigan Limestone Operations	do.	Do.
Georgetown	Texas	Texas Crushed Stone Co.	do.	Do.
Pennsuco	Florida	Tarmac America Inc.	do.	Dredging
White Rock Quarries (1)	Florida	Vecellio & Grogan Inc.	Stone	Dredging
McCook 378	Illinois	Vulcan Materials Co.	do.	Open quarry.
International	New Mexico	IMC Kalium, Carlsbad Potash	Potash	Stoping.
Stoneport Quarry	Michigan	Presque Isle Corp.	Stone	Open quarry.
Bridgeport	Texas	Texas Industries, Inc., Bridgeport Stone Co.	do.	Do.
Thornton	Illinois	General Dynamics Corp., Material Service Corp.	do.	Open quarry and stoping.
Cape Sandy	Indiana	Mulzer Crushed Stone Co., Inc.	do.	Open quarry.
Crushed Limestone Operation	Missouri	Tower Rock Stone Co.	do.	Do.
Norcross	Georgia	Vulcan Materials Co.	Stone	Open quarry.
Sheldon/Peoria	California	Calmat Co., Inc.	Sand and gravel	Open pit.
Pebbly Beach	do.	LG Everist, Inc.	Stone	Open quarry.
Mojave	do.	Onoda Cement Co., California Portland Cement	do.	Do.
Kennesaw	Georgia	Vulcan Materials Co.	do.	Do.
Mount Hope	New Jersey	Mount Hope Rock Products Inc.	do.	Do.
Cedarville	Michigan	Michigan Limestone Operations	do.	Do.

1/ Owing to commodity reporting differences, the rank of individual mining operations may not be available.

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TABLE 6
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINING OPERATIONS
IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT OF TOTAL MATERIAL HANDLED

Type of ore and mining operation 1/	State	Operator	Commodity	Mining method
Metal ores:				
Morenci	Arizona	Phelps Dodge Corp.	Copper	Open pit.
Carlin Mines Complex	Nevada	Newmont Gold Co.	Gold	Open pit and stoping.
Goldstrike	do.	Barrick Gold Corp.	do.	Do.
Robinson	do.	BHP Copper Inc.	Gold and copper	Open pit.
Twin Creeks	do.	Santa Fe Pacific Gold Corp.	Gold	Do.
Chino	New Mexico	Chino Mines Co.	Copper	Do.
Bingham Canyon	Utah	Kennecott, Utah Copper Corp.	do.	Do.
Cyprus Miami (Inspiration)	Arizona	Cyprus Climax Metals Co.	do.	Do.
Sierrita	do.	do.	do.	Do.
Minntac	Minnesota	USX	Iron	Do.
Empire	Michigan	Cleveland-Cliffs, Inc.	do.	Do.
Bagdad	Arizona	Cyprus Climax Metals Co.	Copper	Do.
McCoy Cove	Nevada	Echo Bay Mining Co.	Gold	Do.
Hoyt Lakes	Minnesota	Cleveland-Cliffs, Inc.	Iron	Do.
Golden Sunlight	Montana	Placer Dome U.S. Inc.	Gold	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	do.	Do.
Hibbing	Minnesota	Cleveland-Cliffs, Inc.	Iron	Do.
Cortez	Nevada	Placer Dome U.S. Inc.	Gold	Do.
Pinto Valley	Arizona	BHP Copper Inc.	Copper	Do.
Lone Tree	Nevada	Santa Fe Pacific Gold Corp.	Gold	Do.
Florida Canyon	do.	Pegasus Gold Inc.	do.	Do.
Mesquite	California	Santa Fe Pacific Gold Corp.	do.	Do.
Hycroft (Crofoot-Lewis)	Nevada	Granges Inc.	do.	Do.
Thompson Creek	Idaho	Thompson Creek Metals Co.	Molybdenum	Do.
Thunderbird	Minnesota	EVTAC Mining	Iron	Do.
Industrial minerals:				
Florida mines (6)	Florida	IMC-Agrico Co.	Phosphate rock	Do.
Fort Meade	do.	Cargill Fertilizer Inc.	do.	Do.
Boron	California	U.S. Borax, Inc.	Boron minerals	Do.
Aurora	North Carolina	PCS Phosphate	Phosphate rock	Do.
F E C Quarry	Florida	CSR America Inc.	Stone	Open quarry.
Reed Quarry	Kentucky	Vulcan Materials Co.	do.	Do.
Nichols	Florida	Agrifos L.L.C.	Phosphate rock	Open pit.
Beckmann	Texas	Redland Aggregates North America, Redland Stone Products Co.	Stone	Open quarry.
Hardee	Florida	C F Industries Inc.	Phosphate rock	Open pit.
Calcite Operation	Michigan	Michigan Limestone Operations	Stone	Open quarry.
Georgetown	Texas	Texas Crushed Stone Co.	do.	Do.
Pennsuco	Florida	Tarmac America Inc.	do.	Dredging
White Rock Quarries (1)	do.	Vecellio & Grogan Inc.	do.	Do.
McCook 378	Illinois	Vulcan Materials Co.	Stone	Open quarry.
Stoneport Quarry	Michigan	Presque Isle Corp.	do.	Do.
International	New Mexico	IMC Kalium, Carlsbad Potash	Potash	Stoping.
Bridgeport	Texas	Texas Industries, Inc., Bridgeport Stone Co.	Stone	Open quarry.
Thornton	Illinois	General Dynamics Corp., Material Service Corp.	do.	Open quarry and stoping.
Cape Sandy	Indiana	Mulzer Crushed Stone Co., Inc.	do.	Open quarry.
Crushed Limestone Operation	Missouri	Tower Rock Stone Co.	do.	Do.
Norcross	Georgia	Vulcan Materials Co.	do.	Do.
Pebbly Beach	California	LG Everist, Inc.	do.	Do.
Sheldon/Peoria	do.	Calmat Co., Inc.	Sand and gravel	Open pit.
Mojave	do.	Onoda Cement Co., California Portland Cement	Stone	Open quarry.
Kennesaw	Georgia	Vulcan Materials Co.	do.	Do.

1/ Owing to commodity reporting differences, the rank of individual mining operations may not be available.

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TABLE 7
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES
IN THE UNITED STATES IN 1996, BY SELECTED COMMODITY AND STATE 1/

(Thousand metric tons)

Commodity	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
Metal ores:						
Copper	1,820	W	1,820	432,000	W	432,000
Gold	W	W	W	296,000	3,630	299,000
Iron	61,800	W	61,800	206,000	W	206,000
Platinum and palladium	--	W	W	--	404	404
Zinc	W	220	220	W	6,200	6,200
Industrial minerals:						
Asbestos	10	--	10	W	--	W
Barite	507	W	507	997	273	1,270
Clays	40,100	W	40,100	40,100	W	40,100
Diatomite	698	--	698	1,500	--	1,500
Feldspar 2/	608	--	608	1,050	--	1,050
Garnet	55	--	55	55	--	55
Gypsum	15,100	2,660	17,700	15,100	3,240	18,300
Magnesium compounds	446	--	446	2,190	--	2,190
Mica (scrap)	159	--	159	262	--	262
Phosyhate rock	45,400	--	45,400	174,000	--	174,000
Potash	W	2,430	2,430	W	12,900	12,900
Pumice 3/	612	--	612	612	--	612
Salt	W	32,700	32,700	4,600	32,700	37,300
Sand and gravel:						
Construction	917,000	W	917,000	917,000	W	917,000
Industrial	25,000	--	25,000	25,000	--	25,000
Soda ash	W	10,200	10,200	W	10,200	10,200
Stone:						
Crushed	1,280,000	48,400	1,330,000	1,280,000	48,400	1,330,000
Dimension	1,480	50	1,530	1,480	50	1,530
Talc and pyrophyllite	783	W	783	789	W	789
Vermiculite	164	--	164	W	--	W
States:						
Alabama	56,300	W	56,300	56,300	W	56,300
Alaska	12,500	W	12,500	22,800	W	22,800
Arizona	51,000	W	51,000	387,000	W	387,000
Arkansas	40,000	--	40,000	40,000	--	40,000
California	158,000	W	158,000	200,000	W	200,000
Colorado	42,400	42	42,500	52,800	W	52,800
Connecticut	13,200	--	13,200	13,200	--	13,200
Delaware	2,370	--	2,370	2,370	--	2,370
Florida	128,000	351	129,000	255,000	351	256,000
Georgia	81,200	W	81,200	81,800	W	81,800
Hawaii	6,950	--	6,950	6,950	--	6,950
Idaho	25,400	W	25,400	51,600	368	52,000
Illinois	102,000	W	102,000	102,000	4,300	106,000
Indiana	76,900	W	76,900	76,900	4,600	81,500
Iowa	43,600	6,770	50,300	43,600	6,770	50,300
Kansas	34,600	3,570	38,200	34,600	3,570	38,200
Kentucky	54,500	12,800	67,300	54,500	12,800	67,300
Louisiana	17,500	15,300	32,800	17,500	15,300	32,800
Maine	9,230	--	9,230	9,230	--	9,230
Maryland	34,700	W	34,700	34,700	W	34,700
Massachusetts	26,100	W	26,100	26,100	W	26,100
Michigan	113,000	764	114,000	144,000	764	145,000
Minnesota	91,700	--	91,700	206,000	--	206,000
Mississippi	16,800	--	16,800	16,800	--	16,800
Missouri	74,000	5,410	79,400	74,000	12,300	86,300
Montana	11,800	308	12,200	35,400	810	36,200
Nebraska	17,700	W	17,700	17,700	W	17,700
Nevada	28,600	W	28,600	244,000	1,770	246,000
New Hampshire	9,120	--	9,120	9,120	--	9,120

See footnotes at end of table.

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TABLE 7--Continued
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 1996, BY SELECTED COMMODITY AND STATE 1/

(Thousand metric tons)

Commodity	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
States--Continued:						
New Jersey	36,400	--	36,400	36,400	--	36,400
New Mexico	15,400	2,450	17,900	35,400	14,200	49,600
New York	73,600	3,970	77,600	73,600	4,590	78,200
North Carolina	76,300	--	76,300	82,300	--	82,300
North Dakota	8,380	--	8,380	8,380	--	8,380
Ohio	114,000	4,500	119,000	114,000	4,500	119,000
Oklahoma	42,100	W	42,100	42,100	W	42,100
Oregon	40,800	--	40,800	41,100	--	41,100
Pennsylvania	98,800	4,960	104,000	98,800	4,960	104,000
Rhode Island	3,530	--	3,530	3,530	--	3,530
South Carolina	35,200	--	35,200	40,400	--	40,400
South Dakota	14,700	W	14,700	21,900	W	21,900
Tennessee	61,500	4,170	65,700	61,500	9,300	70,800
Texas	155,000	10,100	165,000	155,000	10,100	165,000
Utah	32,800	W	32,800	89,500	W	89,500
Vermont	8,670	W	8,670	8,670	W	8,670
Virginia	70,900	W	70,900	71,400	W	71,400
Washington	53,900	W	53,900	54,000	W	54,000
West Virginia	14,700	2,900	17,600	14,700	2,900	17,600
Wisconsin	60,400	--	60,400	60,800	--	60,800
Wyoming	12,100	9,110	21,200	12,100	9,110	21,200

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes aplite.

3/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

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TABLE 8
MINING METHODS USED AT SURFACE OPERATIONS
IN THE UNITED STATES, BY COMMODITY, IN 1996

(Percent of total material handled)

Commodity	Preceded by drilling and blasting	Not preceded by drilling and blasting 1/
Metal ores:		
Beryllium concentrate	100	--
Copper	99	1
Gold	99	1
Gold-silver	100	--
Iron	92	8
Magnesium metal	83	17
Molybdenum	100	--
Nickel	5	95
Rare earth metal concentrates	100	--
Silver	100	--
Titanium	--	100
Uranium	--	100
Zinc	100	--
Average	98	2
Industrial minerals:		
Abrasives	100	--
Barite	39	61
Boron minerals	100	--
Bromine	--	100
Clays	--	100
Diatomite	3	97
Emery	100	--
Feldspar 2/	95	5
Garnet	51	49
Greensand marl	--	100
Gypsum	89	11
Iodine	--	100
Iron oxide pigments	82	18
Kyanite	100	--
Lithium minerals	91	9
Magnesite	100	--
Magnesium compounds	57	43
Mica (scrap)	6	94
Olivine	76	24
Perlite	20	80
Phosphate rock	3	97
Potash	--	100
Pumice 3/	48	52
Salt	1	99
Sand and gravel:		
Construction	--	100
Industrial	--	100
Soda ash	--	100
Stone:		
Crushed	98	2
Dimension	21	79
Sulfur (Frasch)	--	100
Talc and pyrophyllite	90	10
Tripoli	97	3
Vermiculite	2	98
Wollastonite	95	5
Zeolites	19	81
Average	49	51
Average, metals and industrial minerals	72	28

1/ Includes drilling and cutting without blasting, dredging, and mechanical excavation and nonfloat washing, and other surface mining methods.

2/ Includes aplite.

3/ Excludes volcanic cinder and scoria; included with crushed and broken stone.

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TABLE 9
EXPLORATION ACTIVITY IN THE UNITED STATES IN 1996, BY METHOD, COMMODITY, AND STATE 1/

(Meters)

	Churn drilling	Diamond drilling	Percussion drilling	Rotary and reverse circulation drilling	Other drilling	Trenching	Total
Commodities:							
Copper	--	20,200	--	55,400	--	--	75,500
Gold	--	131,000	W	723,000	W	3,610	857,000
Lead	--	30,800	W	W	W	--	30,800
Zinc	--	W	195,000	W	W	--	195,000
Other 2/	--	67,700	58,000	239,000	163,000	3	527,000
Total	--	249,000	253,000	1,020,000	163,000	3,620	1,690,000
Percent of total	--	15	15	60	10	(3/)	100
States:							
Alaska	--	39,500	--	23,200	--	1,070	63,800
Arizona	--	22,300	--	W	--	W	22,300
California	--	W	--	124,000	2,080	--	126,000
Idaho	--	6,830	--	19,200	W	2,130	28,200
Kentucky	--	4,260	--	--	--	--	4,260
Missouri	--	30,800	W	W	--	--	30,800
Montana	--	7,880	30	3,340	--	--	11,200
Nevada	--	63,600	W	478,000	W	W	542,000
South Dakota	--	2,090	--	W	--	381	2,470
Undistributed 4/	--	72,100	253,000	369,000	161,000	34	855,000
Total	--	249,000	253,000	1,020,000	163,000	3,620	1,690,000
Percent of all States	--	15	15	60	10	(3/)	100

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."

1/ Data rounded to three significant digits; may not add to totals shown.

2/ Includes beryllium concentrates, boron minerals, diatomite, gypsum, iron ore, iron oxide pigments, olivine, silver, crushed stone, uranium, vermiculite, wollastonite, zeolites, and commodity items indicated by symbol W.

3/ Less than 1/2 unit.

4/ Includes Iowa, Minnesota, New Mexico, New York, North Carolina, Oklahoma, Oregon, South Carolina, Tennesse, Utah, Virginia, Washington, Wyoming, and State items indicated by symbol W.

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MANUFACTURED ABRASIVES

By Ronald F. Balazik

Manufactured abrasives include fused aluminum oxide, silicon carbide, metallic shot and grit, aluminum-zirconium oxide, and boron carbide. This report presents information on fused aluminum oxide, silicon carbide, and alumina-zirconia oxide produced in the United States and Canada; data on metallic shot and grit and on boron carbide produced in the United States also are included. Except where noted, quantities are reported in metric units.

Fused Aluminum Oxide

Legislation and Government Programs.—The Department of Defense reported that the National Defense Stockpile (NDS) at yearend 1996 contained 141,812 tons of crude fused aluminum oxide valued at $33.3 million and 29,882 tons of fused aluminum oxide abrasive grain valued at $15.7 million. However, stockpile goals for crude fused aluminum oxide and fused aluminum oxide abrasive grain were reduced to zero prior to 1996; Federal law authorizes the disposal of all aluminum oxide in the NDS. Thus, in 1996, the Department of Defense sold 40,824 tons of stockpiled crude fused aluminum oxide valued at $8.9 million and 2,633 tons of stockpiled fused aluminum oxide abrasive grain valued at $1.4 million.

Production.—Data in this report on the production, sale, and use of fused aluminum oxide are based on a survey of operations in the United States and Canada conducted by the U.S. Geological Survey (USGS). Data on production and on material sold or used were collected from 5 companies operating 10 plants in the United States and Canada and represented the entire industry. *(See table 1.)*

Total output of fused aluminum oxide in 1996 was 144,000 tons, slightly less than in 1995. Production of regular-grade fused aluminum oxide was 127,000 tons, about the same as in 1995. Production of high-purity fused aluminum oxide in 1996 decreased 15% to 17,000 tons. *(See table 2.)*

Consumption.—Fused aluminum oxide in the form of graded grain has several end uses. The total value of U.S. producer sales of fused aluminum oxide graded grain for all uses was estimated to be over $100 million in 1996. Specific applications of graded grain in 1996 included bonded abrasives, coated abrasives, refractories, tumbling media, blasting abrasives, polishing/ buffing compounds, and antislip abrasives.

Prices.—The USGS does not collect price data on the various grades of fused aluminum oxide. However, it does collect data on the value of output reported by producers. The average value of regular fused aluminum oxide in 1996, as reported by producers, was $353 per ton. The reported average value of high purity fused aluminum oxide in 1996 was $576. Prices of abrasive grain produced from these materials and sold to consumers are significantly higher. In 1996, prices generally ranged from $0.25 to $0.70 per pound for regular-grade grain and from $0.40 to $0.80 per pound for high-purity grain.

Foreign Trade.—Imports of crude fused aluminum oxide decreased sharply in 1996 to 81,100 tons (valued at $35.5 million), while imports of ground and refined fused aluminum oxide rose significantly to 49,400 tons (valued at $37.2 million). Most of the crude imports came from Canada; most of the ground and refined material came from China. A small amount of imported fused aluminum oxide was reexported during 1996.

Exports of all fused aluminum oxide in 1996 increased slightly to 11,900 tons. These exports were valued at $18 million. Most of the exports went to Canada and Mexico.

Silicon Carbide

Legislation and Government Programs.—As of December 31, 1996, the National Defense Stockpile contained 14,458 tons of silicon carbide valued at $6.9 million. Prior to 1996, however, the stockpile goal for silicon carbide was reduced to zero. Thus, under Federal legislation authorizing disposal of all silicon carbide in the NDS, the Department of Defense sold over 4,000 tons of stockpiled silicon carbide (valued at more than $2 million) in 1996.

Production.—The USGS collects production and sales information from all domestic and Canadian producers of silicon carbide. Three companies operating three plants (two in the United States and one in Canada) produced silicon carbide in 1996. Table 2 shows production and estimated production values for these companies in 1995 and 1996.

Consumption.—Silicon carbide in the form of graded grain has several end uses. The total value of U.S. producer sales of silicon carbide graded grain for all uses in 1996 was estimated to be approximately $90 million. End uses of the grain included bonded abrasives, coated abrasives, refractories, tumbling media, blasting abrasives, wiresawing abrasives, polishing/buffing compounds, and antislip abrasives.

Prices.—The USGS does not collect price data on the various grades of silicon carbide. Based on Department of Defense stockpile sales and other information from industry, however, the average value of abrasive-grade silicon carbide at the point of manufacture was estimated to be $490 in 1996.

Foreign Trade.—Imports of crude silicon carbide rose slightly in 1996 to 167,000 tons (valued at $70 million). Imports of silicon carbide in ground or refined form nearly doubled to 14,400 tons (valued at $24 million). Most of the crude imports came from China; one-half of the ground or refined imports came from Brazil. A small amount of imported silicon carbide was reexported in 1996.

Exports of crude silicon carbide declined sharply from 1995 exports to 566 tons (valued at $1.6 million), while exports of

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Mexico; most refined and ground material went to Canada.

Aluminum-Zirconium Oxide

Two firms, Norton Company and Washington Mills, produced fused aluminum-zirconium oxide for abrasive applications (e.g., resin- bonded grinding wheels) in 1996; output was from three plants, two in the United States and one in Canada. In order to protect company proprietary information, the USGS does not publish detailed data regarding this production. Import and export data on aluminum-zirconium oxide are not collected by the U.S. Government.

Boron Carbide

Only one firm, Washington Mills, is known to be a commercial producer of boron carbide in the United States. Boron carbide is used for grinding and lapping operations previously possible only with diamond dust (Wellborn, 1996); it also is molded to form highly wear-resistant products.

Although production data are not available, the USGS has the following U.S. trade information on boron carbide in 1996: U.S. imports reached 196 tons (valued at $4.7 million), primarily from China, Germany, and the Ukraine; exports were 6.8 tons (valued at $0.6 million), principally to Western Europe.

Metallic Abrasives

Production.—Data in this report on the domestic production, sale, and use of metallic abrasives are based on a survey of domestic operations conducted by the USGS. Production and sold or used data were collected from 13 companies operating 14 plants in the United States and accounted for virtually all of the domestic industry. *(See table 3.)*

Steel shot and grit account for nearly all of metallic abrasives produced domestically. *(See table 4.)* The quantity of steel shot and grit produced in 1996 increased slightly relative to 1995 output. Total value grew 4% in 1996 and the average value per ton increased to $441.

During 1996, six companies, including two new firms, reported production of cut wire shot. The production of cut wire shot increased significantly in 1996.

Consumption.—The quantity of steel shot and grit sold or used in 1996 increased slightly relative to 1995; total value increased 3%. The average value per ton sold or used during the year increased slightly to $458. It is estimated that the quantity of cut wire shot sold by domestic producers in 1996 increased significantly.

Prices.—The USGS does not collect price data on metallic abrasives. However, data on the value of production are collected. The values of production and shipments reported by metallic abrasive producers in 1996 are shown in table 4.

Foreign Trade.—U.S. imports of metallic abrasives declined 21% to 20,200 tons in 1996. The value of these imports decreased 16% to $12.2 million. Most of the imports came from Canada. A small quantity of imported metallic abrasives was reexported in 1996.

Domestic exports of metallic abrasives totaled 24,900 tons in 1996, a decline of 20% from those of 1995. The total value of the 1996 exports was $15.2 million, slightly less than the 1995 value. Most of the exports in 1996 went to Canada.

Outlook

Further consolidation of the fused aluminum oxide and silicon carbide industries will continue through closures, acquisitions, and joint ventures worldwide in the remaining 1990's. China will continue to grow as a supplier of both materials in North America and Western Europe; producers in Eastern and Central Europe may become more important suppliers as well. The trends toward consolidation and the emergence of new regional suppliers have been more pronounced in recent years (Bolger, 1996; O'Driscoll, 1997).

Trends in foundries, machine tool industries, metal fabrication plants, and other industrial operations where manufactured abrasives are used for cutting, shaping, and polishing metals will continue to propel demand for these abrasives. However, the substitution of metals by plastics and other materials could curb demand for some of these abrasives. Less influential demand factors include near-net-shape metal casting and environmental regulations that reduce chemical finishing of metals; the former tends to decrease demand for abrasive finishing of metals, while the latter would increase such demand.

Automotive vehicle manufacturing, a major metals consumer, will indirectly influence demand for manufactured abrasives. Consequently, domestic consumption of manufactured abrasives will reflect somewhat the quantity and the metal content of automotive vehicles built in the United States. Some smaller markets (e.g., manufactured abrasives used for machining advanced ceramics and metal matrix composites) show promise of significant growth.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
CRUDE ARTIFICIAL ABRASIVES MANUFACTURERS IN 1996

Company	Location	Product
Dakota Catalyst Products, Inc.	Williston, ND	Fused aluminum oxide (regular and high-purity).
The Exolon-Esk Co.	Hennepin, IL	Silicon carbide.
Do.	Thorold, Ontario, Canada	Fused aluminum oxide (regular).
Treibacher Schleifmittel Corp.	Niagara Falls, NY	Fused aluminum oxide (high-purity).
Do.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Saint-Gobain/Norton Co.	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Worcester, MA	General abrasive processing.
Do.	Chippawa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do.	Shawinigan, Quebec, Canada	Silicon carbide.
Superior Graphite Co.	Hopkinsville, KY	Do.
Washington Mills Electro Minerals (Canada) Corp.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Washington Mills Electro Minerals (U.S.) Corp.	Niagara Falls, NY	Fused aluminum oxide (high-purity), aluminum-zirconium oxide, and boron carbide.
Washington Mills Ltd.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).

TABLE 2
PRODUCTION OF CRUDE SILICON CARBIDE AND FUSED ALUMINUM OXIDE
IN THE UNITED STATES AND CANADA 1/

	1995			1996		
Product	Quantity (metric tons)	Value (thousands)	Yearend stocks	Quantity (metric tons)	Value (thousands)	Yearend stocks
Silicon carbide	75,400 r/	$37,400 e/	9,640	73,600	$36,000 e/	6,760
Aluminum oxide:						
Regular: Abrasives and refractories	126,000	45,100	15,600	127,000	44,900	13,300
High purity	20,100 r/	9,460 r/	774 r/	17,000	9,800	1,870
Total	146,000 r/	54,600 r/	16,400 r/	144,000	54,700	15,200

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 3
U.S. PRODUCERS OF METALLIC ABRASIVES IN 1996

Company	Location	Product (shot and/or grit)
Abrasive Materials, Inc.	Fortville, IN	Cut wire, steel.
Barnsteel Abrasives	Butler, PA	Iron and steel.
Chesapeake Specialty Products	Baltimore, MD	Steel.
Ervin Industries, Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Frohn North America, Inc.	Austell, GA	Cut wire.
Marwas Steel Co.	Scottdale, PA	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Steel.
National Metal Abrasive Co.	Wadsworth, OH	Do.
Peerless Metal Powders & Abrasive	Detroit, MI	Do.
Pellets, Inc.	Tonawanda, NY	Cut wire.
The Platt Brothers, Inc.	Waterbury, CT	Do.
Premier Shot Co.	Cleveland, OH	Do.
The Wheelabrator Co.	Bedford, VA	Steel.

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TABLE 4
ANNUAL PRODUCTION AND SHIPMENTS FOR METALLIC ABRASIVES IN THE UNITED STATES, BY PRODUCT 1/ 2/

Product	Production		Shipments	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:				
Steel shot and grit	234,000	$102,000	214,000	$96,600
Cut wire shot and other 3/	11,400	8,550	12,400	41,900
Total	246,000	110,000	227,000	184,000
1996:				
Steel shot and grit	240,000	106,000	218,000	99,700
Cut wire shot and other 3/	8,060 e/	14,800 e/	8,620	21,100
Total	248,000	121,000	226,000	121,000

e/ Estimated.

1/ Excludes secondary (recycle) producers.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes aluminum, stainless steel, zinc, and chilled iron shot and grit (1995 only).

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ALUMINUM

By Patricia A. Plunkert

Domestic primary aluminum production increased slightly in 1996 to 3.6 million metric tons. Thirteen companies operated 22 primary aluminum reduction plants, and 1 plant remained closed. Montana, Oregon, and Washington accounted for 38% of the production; Kentucky, North Carolina, South Carolina, and Tennessee, 21%; and other States, 41%. The value was estimated to be $5.6 billion.

Aluminum recovered from purchased scrap increased to about 3.3 million tons. Of this recovered metal, 52% came from new (manufacturing) scrap and 48% from old (discarded aluminum products) scrap. Aluminum used beverage can (UBC) scrap accounted for about one-half of the reported old scrap consumption in 1996. The recycling rate for aluminum UBC's increased slightly to 63.5%.

Transportation and the container and packaging industries remained the largest domestic markets for aluminum products in 1996. The transportation industry accounted for an estimated 32% of domestic consumption; containers and packaging, 26%; building and construction, 16%; electrical and consumer durables, 8% each; and other uses, 10%.

U.S. imports for consumption of aluminum materials decreased in 1996 compared with those of the previous year. Although imports from Russia continued to decline from their peak level in 1994, Russia remained the second largest shipper, following Canada, of aluminum materials to the United States. Total exports from the United States also decreased in 1996.

The price of primary aluminum ingot on the domestic and the international markets fluctuated during the year but trended downward before recovering near the end of the year. The annual average price of primary ingot was substantially lower than that in 1995. Prices in the aluminum scrap markets paralleled the general trend of primary ingot prices during the year.

World inventory levels at the end of 1996 were mixed. Inventories held by the London Metal Exchange (LME) increased by about 400,000 tons. World producer stocks, however, decreased by a similar amount, as reported by the International Primary Aluminium Institute (IPAI). U.S. inventories also decreased slightly during the year.

Primary aluminum was produced in 44 countries in 1996. The United States was the largest producer with 17% of the world total, followed by Russia with 14% and Canada with 11%. World metal production increased slightly compared with that of 1995.

Legislation and Government Programs

The 1997 Defense Authorization Act authorized the Defense Logistics Agency to sell the entire inventory of aluminum metal from the National Defense Stockpile (NDS) in fiscal year 1997, beginning October 1996. There were no sale offers in calendar year 1996, and the NDS inventory at the end of the year remained at about 57,000 tons.

Production

Primary.—Domestic primary aluminum production, totaling 3,577,222 tons, increased by 6% compared with that in 1995. *(See tables 1 and 2.)* Production data were obtained from the 13 domestic producers, all of whom responded to the U.S. Geological Survey's (USGS) request for data.

Workers at 10 primary aluminum smelters ratified new labor agreements during the year. The Aluminum Co. of America (Alcoa), Reynolds Metals Co., the United Steelworkers of America (USW), and the Aluminum, Brick, and Glass Workers International Union (ABG) announced the signing of a new 6-year contract covering 16,500 workers at 30 locations, including 9 smelters, in 18 States. The contract reportedly includes wage increases totaling $1.15 per hour during the first 5 years and improved pension benefits (Platt's Metals Week, 1996i). The USW and Ormet Corp. reported the ratification of a new 3-year contract covering workers at Ormet's Hannibal, OH, primary aluminum smelter. The agreement reportedly provided for an 85-cent-per-hour increase in direct wages during the next 3 years plus increases in the profit-sharing program (Regan, 1996d).

The ABG agreed to merge with the USW. The merger was scheduled to become effective on January 20, 1997. The addition of the 40,000 ABG members reportedly will increase the USW membership to about 740,000 workers (Robertson, 1996).

Southwire Co. announced plans to add a 50,000-ton-per-year (t/yr) potline at its NSA smelter in Hawesville, KY. A company spokesman reported that two criteria must be met before a final decision is made on the proposed expansion—securing the necessary environmental permits and negotiating a long-term power-supply agreement (Platt's Metals Week, 1996h).

Alumax Inc. announced the sale of a 23% interest in the 205,000-t/yr Mount Holly, SC, primary aluminum smelter to Glencore Primary Aluminum Co. Following the sale, Alumax retained a 50.33% interest in the plant, and Glencore International AG's interest rose to 49.67% through its subsidiaries Glencore Primary Aluminum (23%) and Century Aluminum Co. (26.67%) (Alumax Inc., 1996c).

Brett Wilcox, president and owner of Northwest Aluminum Corp., acquired 60% of Goldendale Aluminum Co. Goldendale

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previously had acquired Columbia Aluminum Co.'s 168,000-t/yr primary aluminum smelter in Goldendale, WA, and its alumina unloading facility in Portland, OR. Goldendale's Employee Stock Ownership Plan retained 40% of the company's preferred stock. Ken Peterson, former CEO of Columbia Aluminum, retained 100% ownership of Columbia's extrusion, recycling, metal trading, and diversified businesses and will operate these facilities under the name "Columbia Ventures Corp." (Platt's Metals Week, 1996b). Hydro Aluminum Louisville Inc., a subsidiary of Norsk Hydro A/S, reported the signing of a 10-year toll-conversion contract with Goldendale for 100% of the smelter's output to become effective on January 1, 1997 (Platt's Metals Week, 1996f).

Ormet reached an agreement with American Electric Power Co. (AEP) on an interim power-supply arrangement from 1997 through 1999 for Ormet's aluminum smelter and rolling mill in Hannibal, OH; the previous 30-yr power-supply contract will expire in 1997. Ormet reported that it would continue to search for a power supplier to meet its long-term energy requirements (Regan, 1996b).

Intalco Aluminum Corp., a subsidiary of Alumax, announced that it has agreed to annual purchases of 770 gigawatt hours (GWh) of electricity and up to 145 megawatts (MW) from Powerex, the export division of BC Hydro of Vancouver, WA. The 5-year agreement will continue through September 30, 2000. In a separate agreement, Bonneville Power Administration will continue to supply the majority of the Ferndale, WA, smelter's full production capacity power load of 460 MW/yr (Platt's Metals Week, 1996g).

Alumax announced the sale of several of its fabricated products businesses in Western Europe and the United States to Euramax International, Ltd. The sale included 5 companies in Europe and more than 30 plants and service centers in the United States. Euramax is a new company incorporated under the laws of England and Wales by CVC European Equity Partners, L.P. and several Citicorp entities (Alumax Inc., 1996d). To handle the U.S. operations, Euramax announced the formation of Amerimax Fabricated Products Inc. (Regan, 1996a).

Universal Alloy Corp. announced its first expansion outside the West Coast with the construction of a new facility in Canton, GA, that will increase by one-third the company's capacity to produce aluminum extrusions for the aircraft industry. The new plant was expected to give Universal Alloy a presence on the East Coast and access to the European market that will compliment its existing West Coast location, which also serves the Pacific Rim. The plant is scheduled to begin operations in January 1998 (Haflich, 1996).

Kaiser Aluminum & Chemical Corp. broke ground for its first commercial Micromill facility, near Reno, NV. The Micromill process is a proprietary, compact, high-speed process for the continuous casting and rolling of thin-strip aluminum sheet. The company expects the Nevada facility to begin startup in the first half of 1997 and anticipates beginning limited customer shipments of can sheet from the facility by the second half of 1997 (Kaiser Aluminum & Chemical Corp., 1997).

Kaiser also announced plans to expand the heat-treat capacity at its Trentwood, WA, rolling mill to about 60,000 t/yr from its current capacity of 45,000 t/yr. The expansion will enable the company to increase the range of its heat-treat products, including wide heat-treated sheet for the aerospace industry. The $45-million project is scheduled to be completed in about 2 years (Kaiser Aluminum & Chemical Corp., 1997).

In late April, Alcoa commissioned the largest vertical heat-treat furnace in North America at its Davenport, IA, plant that tripled the plant's capacity for wide-width fuselage sheet. Construction also began on a horizontal plate heat-treating furnace that will increase plate capacity by 50%. Alcoa expects this capacity, part of a $75-million investment to meet aerospace and automotive demand, to be operational in early 1997 (Aluminum Company of America, 1997).

Two of the Nation's major independent aluminum rolling mills, Commonwealth Aluminum Corp. and CasTech Aluminum Group Inc., agreed to a merger that would combine the companies' capabilities of continuous casting and conventional rolling technologies. The combined company reportedly will have the capacity to produce more than 400,000 t/yr of aluminum sheet plus about 145,000 kilometers per year of aluminum electrical products (Regan, 1996c).

Alumax Extrusions Inc., a subsidiary of Alumax Inc. and one of the largest extruders of custom, soft-alloy aluminum shapes in the United States with annual shipments of about 135,000 tons, announced the acquisition of Cressona Aluminum Co. Cressona manufactures and ships about 160,000 t/yr of standard and custom extruded shapes, extruded rod and bar products, and structural and seamless pipe and tube. Alumax Extrusions and Cressona have a combined total of 40 extrusion presses ranging in size from 750 to 6,000 tons (Alumax Inc., 1996b).

Secondary.—Metal recovered from new and old scrap reached a historic high of about 3.3 million tons in 1996, according to data derived by the USGS from its "Aluminum Scrap" survey. *(See tables 3, 4, and 5.)* Of the 90 companies and (or) plants to which monthly or annual survey requests were sent, 71 responded, representing 82% of the total scrap consumed shown in table 4.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries Inc., 62.8 billion aluminum beverage cans were recycled in the United States during 1996. The recycling rate, based on the number of cans shipped during the year, was 63.5%, a slight increase from the 62.2% recycling rate reported in 1995. According to the organizations' joint press release, aluminum beverage cans produced domestically in 1996 had an average 51.6% postconsumer recycled content, the highest content percentage of all packaging materials.

David J. Joseph Co. and George Koch Sons Inc. announced the formation of a joint venture to construct a new recycling plant in Henderson, KY. The venture, Audubon Metals, will process automobile shredder residue (ASR) and produce aluminum alloy for diecasting. Shredder residue will be supplied by Joseph, which owns and operates eight fragmentizers throughout the United States. Audubon will

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separate aluminum from the ASR and smelt and alloy the scrap aluminum into secondary aluminum ingot (American Metal Market, 1996b).

Minerva Aluminum Co. Inc. announced the startup of a third specialty scrap melting furnace at its Minerva, OH, tolling facility. The plant uses a proprietary process for melting scrap aluminum castings contaminated with iron that is designed to prevent the molten aluminum from absorbing the iron during melting. According to the company president, the process also prevents the loss of magnesium and strontium, which are usually casualties in conventional melting furnaces (American Metal Market, 1996c).

Imco Recycling Inc. and Zemex Corp. announced their intention to set up a joint-venture project for the processing of aluminum dross and salt cake. The agreement reportedly calls for technology to be provided by Alumitech Inc., a wholly owned subsidiary of Zemex, and for feedstock to be supplied by Imco. Alumitech technology treats chloride-based drosses, the so-called black drosses, and salt cake materials from waste products generated in recycling aluminum scrap. According to the Zemex president, the Alumitech process not only separates the aluminum and commercial oxides but also can recycle the remaining materials into commercially salable products, hence completely avoiding landfilling (American Metal Market, 1996a).

Consumption

The transportation industry, accounting for about 28% of total U.S. shipments of aluminum products, remained the largest domestic consumer of aluminum. *(See tables 6 and 7.)* Automotive uses in passenger cars and light trucks dominate this end-use market.

The use of aluminum by the automotive industry continued to grow. The "Big Three" automakers have announced new automotive designs that will expand the use of aluminum materials. Some of the new aluminum-intensive vehicles are General Motors Corp.'s new electric vehicle, the EV1; Chrysler Corp.'s concept cars, the Intrepid ESX (Dodge) and the Prowler (Plymouth); and Ford Motor Co.'s concept car, the Indigo.

Alcoa, Reynolds, and Kaiser announced plans to expand their production of aluminum wheels. Alcoa began construction of a $20-million wheel production facility at its Cleveland plant. This is the first phase of a multiphase plan to increase production of forged aluminum wheels to meet market demand for U.S. light trucks. Alcoa and Superior Industries International Inc. formed a company to produce cast aluminum wheels for commercial trucks and buses at Superior's Van Nuys, CA, facility. Commercial production levels were expected to be reached by mid-1997 (Aluminum Company of America, 1997). Reynolds began construction of a facility in Lebanon, VA, to manufacture aluminum wheels by using a process that combines Reynolds' computer-controlled, flow-formed casting technology with forging to produce lightweight wheels that have added styling flexibility (Reynolds Metals Co., 1997). Kaiser announced that it had signed a letter of intent with Accuride Corp. to form a joint venture to design, manufacture, and market aluminum wheels for the commercial truck and trailer industry (Kaiser Aluminum & Chemical Corp., 1997).

Reynolds reported that it had started a $5-million casting complex at its McCook, IL, sheet and plate facilities that doubled the company's aluminum-lithium capacity. The company is the main supplier of AA2195 aluminum-lithium plate and extrusion products for use on the space shuttle's new external fuel tank. The AA2195 alloy reportedly is 30% stronger and weighs 5% less than the alloy it is replacing and is expected to play a major role in a 3,400-kilogram reduction in the weight of the current external tank (Metal Bulletin, 1996g).

Stocks

Inventories of aluminum ingot, mill products, and scrap at reduction and other processing plants, as reported by the U.S. Department of Commerce, decreased from 2.0 million tons at yearend 1995 to 1.83 million tons at yearend 1996.

The LME reported that its U.S. warehouses held about 12,400 tons of primary aluminum metal ingot at yearend 1996, a slight decrease from the approximately 13,800 tons of metal held in these warehouses at yearend 1995. The LME also reported that aluminum alloy ingot at its U.S. warehouses at yearend 1996 totaled 20,100 tons, a significant decrease from the 30,900 tons of alloy held at yearend 1995.

Because there were no releases of metal from the NDS during the year, the inventory level remained at 57,000 tons.

Prices

The monthly average U.S. market price of primary aluminum metal, as reported by Platt's Metals Week, fluctuated during the year but followed a general downward trend before recovering near the end of the year. The monthly average price began the year at 75.2 cents per pound and posted a low of 64.4 cents per pound in October. By December, the monthly average had recovered to 72.2 cents per pound. The average price for the year was 71.35 cents per pound, a substantial decrease compared with the 1995 average annual price of 85.88 cents per pound.

The LME cash price for high-grade primary aluminum ingot followed the same general trend as the U.S. market price. The 1996 average annual LME cash price was 68.3 cents per pound.

Purchase prices for aluminum scrap, as quoted by American Metal Market (AMM), followed the trend of primary ingot prices and closed the year at slightly lower levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 52 to 52.5 cents per pound; old sheet and cast, 47 to 49 cents per pound; and clean, dry aluminum turnings, 48 to 48.5 cents per pound.

Aluminum producers' buying price range for processed and delivered UBC's, as quoted by AMM, fluctuated during the year from a high of 58 to 60 cents per pound at the beginning of the

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year and during the months of April and May to a low of 47 to 48 cents per pound during June and July. At the end of the year, the price ranged from 53 to 54 cents per pound. Resource Recycling published a monthly transaction price for aluminum UBC's in its Container Recycling Report. The average annual UBC transaction price for 1996 was 54.7 cents per pound, a substantial decrease from the 1995 annual average of 66.7 cents per pound.

The yearend indicator prices, as published in AMM, for selected secondary aluminum ingots also decreased compared with those of 1995 and were as follows: alloy 380 (1% zinc content), 79.37 cents per pound; alloy 360 (0.6% copper content), 84.44 cents per pound; alloy 413 (0.6% copper content), 84.66 cents per pound; and alloy 319, 81.50 cents per pound. Platt's Metals Week published an annual average U.S. price of 67.3 cents per pound for A-380 alloy (3% zinc content). The average annual LME cash price for a similar 380 alloy was 59 cents per pound.

Foreign Trade

Total exports of aluminum from the United States decreased in 1996, reversing an upward trend that began in 1994. Although exports of crude metal and alloys increased, semifabricated materials and scrap exports decreased compared with those of 1995. Canada, Japan, and Mexico, in decreasing order of shipments, accounted for about two-thirds of total U.S. exports. *(See tables 8 and 9.)*

Imports for consumption continued to decrease in 1996. Although imports decreased in all categories, as shown in table 11, the largest decrease was in semifabricated materials. Canada remained the major source country, supplying about two-thirds of total imports. Russia remained the second largest supplier of aluminum materials; total imports from Russia, however, continued to decline following the rapid growth of shipments between 1991 and 1994. *(See tables 10 and 11.)*

World Review

World production of primary aluminum metal increased slightly in 1996. *(See table 12.)* Total world inventories of aluminum were relatively unchanged — an increase in LME inventories was balanced by a decline in producer inventories. World metal prices fluctuated during the year and finished the year lower than yearend 1995 prices.

Unwrought primary aluminum inventories held by members of IPAI decreased from 2.0 million tons at yearend 1995 to 1.69 million tons at yearend 1996. IPAI total metal inventories, including secondary aluminum, decreased from 3.57 million tons at yearend 1995 to 3.14 million tons at yearend 1996.

Inventories of primary aluminum metal held by the LME increased during most of 1996 before turning slightly downward during the last 2 months of the year. By the end of the year, inventories had increased to 951,000 tons from 584,000 tons at the end of 1995.

Argentina.—Aluminio Argentino SAIC (Aluar) announced a formal decision to proceed with a planned $300-million expansion at its 185,000-t/yr Puerto Madryn primary aluminum smelter. The expansion, scheduled for completion in mid-1999, will use Pechiney technology that could increase the smelter's capacity by 72,000 t/yr (Metal Bulletin, 1996a).

Austria.—Oesterreichische Industrieholding AG, the government holding company, reportedly has agreed to sell Austria Metall AG to a consortium led by Klaus Hammerer (40%), chairman of Austria Metall; Constantia (40%), a private Austrian concern; and the employees of Austria Metall (20%). Austria Metall holds interests in primary aluminum smelters in Canada and Germany (CRU, 1996).

Brazil.—According to the Brazilian aluminum association, Associacao Brasileira do Aluminio (Abal), aluminum can production capacity in Brazil should increase to 11.6 billion cans per year from the current annual capacity of 4.2 billion cans. Expansions are underway at Reynold's Latasa subsidiary, which has been producing aluminum cans in Brazil since 1990. In addition, new canmaking facilities are planned by Crown Cork Embalagens, a joint venture of Crown Cork and Grupo Petropar; American National Can, a Pechiney subsidiary; and Latapak Ball, a subsidiary of Ball Corp. and Grupo Mariani (Metal Bulletin, 1996b).

Canada.—Alcan Aluminium Ltd. and Canadian Auto Workers Local 2301 announced the ratification of a new 3-year labor agreement covering 1,300 workers at Alcan's Kitimat primary aluminum smelter in British Columbia. The agreement reportedly contains a 3% wage increase in each of the 3 years of the contract, a $2,500-lump-sum payment in the first year, and a cost of living allowance in the second and third years (Alcan Aluminium Ltd., 1996).

Alcan established a project team to evaluate the construction of a new 350,000-t/yr smelter in Alma, Quebec. Environmental impact studies have begun, and an agreement-in-principle was reached with Hydro-Quebec that ensures that the smelter will have access to sufficient power at a competitive cost. A final decision on this project is not expected to be made until late 1997 or early 1998 (Alcan Aluminium Ltd., 1997).

Chile.—Noranda Aluminum Inc. is seeking partners for its proposed $1.2-billion Alumysa smelter complex near the port of Aysen. Full plans call for a 270,000-t/yr primary aluminum smelter, two hydroelectric powerplants, and port facilities. Basic engineering on the venture reportedly has been completed, and an environmental impact study is underway. If a decision to proceed is made, then construction of the complex is expected to take about 4 years (Metal Bulletin, 1996f).

China.—In April, Alumax and Reynolds announced the formation of joint ventures to produce light-gauge aluminum foil for China's food, pharmaceutical, and tobacco industries. Alumax and Yunnan Aluminum Processing Factory in Kunming announced a $70-million joint venture, Yunnan Xinmeilu Aluminum Foil Co. Ltd., for the production of 8,000 to 10,000 t/yr of foil. The venture will upgrade an existing common alloy sheet plant by using Alumax technology (Alumax Inc., 1996a). Reynolds acquired an interest in Bohai Aluminium Industries Ltd., which runs a fabricating facility east of Beijing that

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produces aluminum foil and extrusions (Reynolds Metals Co., 1997).

Egypt.—The Aluminium Company of Egypt (Egyptalum) announced that the addition of a prebaked potline to its 180,000-t/yr Nag Hammadi primary aluminum smelter is scheduled to come on-line in 1997. The potline, containing 92 pots, will increase capacity at the plant by 55,000 t/yr (Metal Bulletin, 1996c).

Hungary.—Inota Aluminium Works, a subsidiary of Hungarian aluminum producer Hungalu Magyar Aluminiumipari, was recently privatized when Hungary's State Privatization and Property Management Corporation sold a majority of shares in the 34,000-t/yr Inota aluminum smelter to Magyar Aluminium Kft. Two smaller smelters, Ajka (22,000 t/yr) and Tatabanya (17,000 t/yr), were considered to be too uneconomic to privatize and were closed (Metal Bulletin, 1996d).

Iceland.—According to the Icelandic Energy Marketing Agency, an agreement with the U.S. aluminum producer, Columbia Venture Corp., was expected to be finalized for the construction of a 60,000-t/yr aluminum smelter. Columbia reportedly purchased the Toging smelter in Germany and was planning to reconstruct it on a site in Iceland. Reconstruction could start early next year, and production could begin in mid-1998 (Mining Journal, 1996b).

India.—Hindalco Industries Ltd. announced plans to expand capacity from 190,000-t/yr to 242,000-t/yr at its Renukoot smelter during the next 2 years. Hindalco is also considering the possibility of building a 200,000-t/yr greenfield smelter in the State of Orissa (Rao, 1996).

Italy.—In March, Alcoa completed the acquisition of the principal operating assets of Alumix S.p.A., Italy's state-owned integrated aluminum producer. Aluminum smelters at Portovesme and Fusina, which have a combined annual capacity of 180,000 tons, were among the assets purchased (Aluminum Company of America, 1997).

Kuwait.—The Kuwaiti Ministry of Finance has approved plans by Raytheon Co. of the United States to build a 230,000-t/yr primary aluminum smelter. The project, worth about $1 billion, reportedly would involve local and foreign partners. Although the finance ministry has approved the plans, other licenses will have to be obtained from other government departments before the plan can proceed (Mining Journal, 1996c).

Mozambique.—Gencor Ltd. received government approval for its proposed $1.2-billion primary aluminum smelter project. The 245,000-t/yr smelter, Mozal, would be located in Maputo Province. A final decision on the project is expected next year, pending the participation of equity partners and the signing of a competitively priced electricity supply contract (Platt's Metals Week, 1996c).

Norway.—Norsk Hydro A/S announced the upgrade of its 220,000-t/yr Karmoy smelter. The upgrade involves the addition of 66 new cells, resulting in an increased capacity of 35,000 t/yr. The project was expected to be completed in about 18 months (Platt's Metals Week, 1996e).

Oman.—Oman may be set to join the ranks of aluminum producers if a proposal for a major new aluminum smelter is approved. The $2.4-billion project is expected to be located near the port of Sohar and includes a 480,000-t/yr smelter and a natural-gas-fired powerplant (Mining Journal, 1996a).

South Africa.—Gencor Ltd. announced that it had reached an agreement with the state-owned Industrial Development Corp. to purchase its 32.15% stake in Alusaf Ltd. Alusaf operates two primary aluminum smelters at Richards Bay with a total capacity of 636,000 t/yr. The agreement increases Gencor's share in Alusaf to 73%. Gencor plans to make similar offers to minority shareholders and to take full control of Alusaf (Platt's Metals Week, 1996d).

Turkey.—Plans are being revived to expand capacity at the Seydisehir smelter in southern Turkey as part of the government's drive to strengthen the country's mineral sector. The $225-million expansion will increase capacity from 60,000 t/yr to 100,000 t/yr and will replace the existing Soderberg equipment with prebake technology. Construction was expected to begin in 1997 and will take an estimated 30 months to complete (Mining Journal, 1996d).

United Kingdom.—British Alcan Aluminium plc, a subsidiary of Alcan Aluminium Ltd., completed the sale of 12 downstream businesses to a group of investors. The new entity will be known as British Aluminium Ltd. The investors include Mercury Development Capital, Morgan Grefell Development Capital, and CVC Capital Partners. British Alcan will continue to operate the UK's aluminum smelters (Platt's Metals Week, 1996a).

Later in the year, British Alcan announced a 2-yr investment plan to upgrade and refurbish potline No. 1 at its 130,000-t/yr Lynemouth smelter in Northumberland. The 70,000-t/yr potline has been closed since 1991 (Metal Bulletin, 1996e).

Outlook

Barring any sudden economic shocks during the next few years, demand for and production of aluminum should continue to increase at a slow and steady pace. Capacity that was temporarily closed a few years ago is slowly coming back on-stream, and many producers are taking this opportunity to upgrade these closed potlines. Companies are once again looking at the possibility of expanding existing facilities or building new smelters. Many of these projects, however, are very early in the planning stages, which could lead to supply shortages in the not too distant future if there is a sudden increase in the demand for aluminum.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT ALUMINUM STATISTICS 1/

(Thousand metric tons unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Primary production	4,042	3,695	3,299	3,375	3,577
Value (million dollars)	$5,130	$4,340	$5,180	$6,390	$5,630
Price: (average cents per pound)					
U.S. market (spot)	57.5	53.3	71.2	85.9	71.3
Inventories (December 31)					
Aluminum industry 2/	1,880	1,980	2,070	2,000	1,830
LME stocks in U.S. warehouses	214	168	16	14	12
National Defense Stockpile	57	57	57	57	57
Secondary recovery 3/	2,760	2,940	3,090	3,190	3,290
New scrap	1,140	1,310	1,580	1,680	1,710
Old scrap	1,610	1,630	1,500	1,510	1,570
Exports (crude and semicrude)	1,450	1,210	1,370	1,610	1,500
Imports for consumption (crude and semicrude)	1,730	2,540	3,380	2,970	2,810
Aluminum industry shipments 4/	6,810	7,300	8,160	8,260 r/	8,260
Supply, apparent 5/	6,870	7,920	8,460	8,010	8,340
Consumption, apparent 6/	5,730	6,600	6,880	6,320	6,620
World: Production	19,500	19,800	19,200	19,900 r/	20,700 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except "prices" and "Primary production."

2/ Includes ingot, semifabricated material, and scrap. Data from Current Industrial Reports, Series M33-D, U.S. Department of Commerce, Bureau of the Census.

3/ Metallic recovery from purchased, tolled, or imported new and old scrap expanded for full industry coverage.

4/ Shipped to domestic industry.

5/ Defined as domestic primary metal production + secondary recovery + imports - exports + adjustments for Government and industry stock changes.

6/ Apparent supply less recovery from purchased new scrap.

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TABLE 2
PRIMARY ANNUAL ALUMINUM PRODUCTION CAPACITY IN THE UNITED STATES, BY COMPANY 1/

Company	Yearend capacity (thousand metric tons) 1995	1996	1996 ownership (percent)
Alcan Aluminum Corp.:			
Sebree, KY	186	186	Alcan Aluminum Ltd., 100%.
Alumax Inc.:			
Ferndale, WA (Intalco)	275	272	Alumax Inc., 61%; Mitsui & Co., 23%; TosTem Corp., 9%; YKK Corp., 7%.
Frederick, MD (Eastalco)	174	174	Do.
Mount Holly, SC	184	205	Alumax, 50.3%; Century Aluminum Co., 26.7%; Glencore Primary Aluminum Co., 23%.
Total	633	651	
Aluminum Co. of America: 2/			
Alcoa, TN	210	210	Aluminum Co. of America, 100%.
Badin, NC	115	115	Do.
Evansville, IN (Warrick)	300	300	Do.
Massena, NY	125	125	Do.
Rockdale, TX	315	315	Do.
Wenatchee, WA	220	220	Do.
Total	1,290	1,290	
Columbia Falls Aluminum Co.:			
Columbia Falls, MT	168	168	Montana Aluminum Investors Corp., 100%.
Goldendale Aluminum Co.:			
Goldendale WA	168	168	Private interest, 60%; employees, 40%.
Kaiser Aluminum & Chemical Corp.:			
Mead, WA (Spokane)	200	200	MAXXAM Inc., 100%.
Tacoma, WA	73	73	Do.
Total	273	273	
NSA:			
Hawesville, KY	188	186	Southwire Co., 100%.
Noranda Aluminum Inc.:			
New Madrid, MO	215	215	Noranda Mines Ltd., 100%.
Northwest Aluminum Corp.:			
The Dalles, OR	82	82	Private interests, 100%.
Ormet Corp.:			
Hannibal, OH	254	256	Ormet Corp., 100%.
Ravenswood Aluminum Corp.:			
Ravenswood, WV	168	168	Century Aluminum Co., 100%
Reynolds Metals Co.:			
Longview, WA	204	204	Reynolds Metals Co., 100%.
Massena, NY	123	123	Do.
Troutdale, OR	121	121	Do.
Total	448	448	
Vanalco Inc.:			
Vancouver, WA	116	116	Vanalco Inc., 100%.
Grand total	4,180	4,200	

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Individual plant capacities are U.S. Geological Survey estimates based on company reported total.

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TABLE 3
U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP 1/, BY CLASS 2/

(Metric tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
1995:			
Secondary smelters	1,300,000	978,000	1,050,000
Integrated aluminum companies	1,400,000	1,160,000	1,240,000
Independent mill fabricators	676,000	585,000	625,000
Foundries	102,000	84,000	90,300
Other consumers	10,800	9,570	9,600
Total	3,480,000	2,820,000	3,010,000
Estimated full industry coverage	3,690,000	2,980,000	3,190,000
1996:			
Secondary smelters	1,440,000	1,030,000	1,100,000
Integrated aluminum companies	1,410,000	1,170,000	1,250,000
Independent mill fabricators	709,000	613,000	655,000
Foundries	95,300	78,500	84,400
Other consumers	9,910	8,730	8,760
Total	3,660,000	2,900,000	3,100,000
Estimated full industry coverage	3,880,000	3,070,000	3,290,000

1/ Excludes recovery from other than aluminum-base scrap.
2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 4
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP 1/ AND SWEATED PIG IN 1996 2/

(Metric tons)

Class of consumer and type of scrap	Stocks, Jan. 1	Net receipts 3/	Consump-tion	Stocks, Dec. 31
Secondary smelters:				
New scrap:				
Solids	7,130 r/	138,000	138,000	7,760
Borings and turnings	4,170 r/	210,000	210,000	4,590
Dross and skimmings	3,730	326,000	326,000	3,670
Other 4/	2,560 r/	211,000	211,000	2,740
Total	17,600 r/	886,000	885,000	18,800
Old scrap:				
Castings, sheet, clippings	13,600 r/	419,000	411,000	21,100
Aluminum-copper radiators	898 r/	15,700	15,700	850
Aluminum cans 5/	560 r/	69,300	69,500	339
Other 6/	443	45,500	45,100	838
Total	15,500 r/	549,000	542,000	23,100
Sweated pig	2,500 r/	5,560	5,600	2,460
Total secondary smelters	35,600 r/	1 440,000	1 430,000	44,300
Integrated aluminum companies, foundries, independent mill fabricators, other consumers:				
New scrap:				
Solids	15,600	804,000	794,000	25,400
Borings and turnings	27	28,300	27,900	375
Dross and skimmings	136	12,500	12,400	260
Other 4/	8,330	218,000	215,000	11,900
Total	24,100	1,060,000	1,050,000	37,900
Old scrap:				
Castings, sheet, clippings	7,970 r/	355,000	353,000	10,300
Aluminum-copper radiators	145 r/	2,260	2,090	314
Aluminum cans	34,600	791,000	801,000	24,900
Other 6/	340	16,700	16,500	489
Total	43,100 r/	1,170,000	1,170,000	35,900
Sweated pig	221 r/	4,390	4,270	342
Total intergrated aluminum companies, etc.	67,400 r/	2,230,000	2,230,000	74,100
All scrap consumed:				
New scrap:				
Solids	22,700	942,000	932,000	33,100
Borings and turnings	4,200 r/	239,000	238,000	4,970
Dross and skimmings	3,860	339,000	339,000	3,930
Other 4/	10,900 r/	429,000	426,000	14,600
Total	41,700 r/	1,950,000	1,930,000	56,600
Old scrap:				
Castings, sheet, clippings	21,600 r/	774,000	764,000	31,300
Aluminum-copper radiators	1,040 r/	17,900	17,800	1,160
Aluminum cans	35,200 r/	861,000	871,000	25,200
Other 6/	783	62,200	61,700	1,330
Total	58,600 r/	1,710,000	1,710,000	59,000
Sweated pig	2,720 r/	9,940	9,860	2,800
Total of all scrap consumed	103,000 r/	3,670,000	3,660,000	118,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes imported scrap. According to reporting companies, 15.51% of total receipts of aluminum-base scrap, or 567,000 metric tons, was received on toll arrangements.

3/ Includes inventory adjustment.

4/ Includes data on foil, can stock clippings, and other miscellaneous.

5/ Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.

6/ Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

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TABLE 5
PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES 1/

(Metric tons)

	1995		1996	
	Production	Net shipments 2/	Production	Net shipments 2/
Diecast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	49,600	49,700	74,500	73,400
380 and variations	570,000	569,000	473,000	474,000
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	12,900	12,500	24,100	24,000
No. 12 and variations	W	W	W	W
No. 319 and variations	86,400	85,400 r/	132,000	132,000
F-132 alloy and variations	30,900	31,000 r/	45,000	44,800
Al-Mg alloys	639	639	685	685
Al-Zn alloys	2,200	2,160	3,430	3,430
Al-Si alloys (0.6% to 2.0% Cu)	10,900	10,700 r/	9,980	10,600
Al-Cu alloys (1.5% Si, maximum)	977	980	936	937
Al-Si-Cu-Ni alloys	1,060	1,060	1,130	1,110
Other	4,280	3,750 r/	4,180	4,270
Wrought alloys: Extrusion billets	163,000	163,000	153,000	152,000
Miscellaneous:				
Steel deoxidation	--	--	(3/)	(3/)
Pure (97.0% Al)	--	--	--	--
Aluminum-base hardeners	5,380	4,610	93	93
Other 4/	39,600	38,500	82,700	86,000
Total	978000	973,000	1,000,000	1,010,000
Less consumption of materials other than scrap:				
Primary aluminum	41,800	--	46,400	--
Primary silicon	74,900 r/	--	80,600	--
Other	3,730	--	4,930	--
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot 5/	858,000	XX	872,000	XX

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Sand and permanent mold: Other." XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes inventory adjustment.
3/ Withheld to avoid disclosing company proprietary data; included with "Miscellaneous: Other."
4/ Includes other die-cast alloys and other miscellaneous.
5/ No allowance made for melt-loss of primary aluminum and alloying ingredients.

TABLE 6
DISTRIBUTION OF END-USE SHIPMENTS OF ALUMINUM PRODUCTS IN THE UNITED STATES, BY INDUSTRY 1/

	1995		1996	
Industry	Quantity (thousand metric tons)	Percent of grand total	Quantity (thousand metric tons)	Percent of grand total
Containers and packaging	2,310	24.1	2,180	22.8
Building and construction	1,220	12.7	1,310	13.7
Transportation	2,610 r/	27.3 r/	2,630	27.6
Electrical	657	6.9	665	7.0
Consumer durables	621	6.5	633	6.6
Machinery and equipment	570 r/	6.0	567	5.9
Other markets	279	2.9	281	2.9
Total to domestic users	8,260 r/	86.4	8,260	86.5
Exports	1,310	13.7	1,290	13.5
Grand total	9,570 r/	100.0	9,550	100.0

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: The Aluminum Association Inc.

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TABLE 7
U.S. NET SHIPMENTS 1/ OF ALUMINUM WROUGHT AND CAST PRODUCTS, BY PRODUCERS 2/

(Thousand metric tons)

	1995	1996 p/
Wrought products:		
Sheet, plate, foil	4,900 r/	4,370
Rod, bar, pipe, tube, and shapes	1,540 r/	1,550
Rod, wire, cable	526 r/	352
Forgings (including impacts)	103	92
Powder, flake, paste	60	65
Total	7,130 r/	6,430
Castings:		
Sand	207	NA
Permanent and semipermanent mold	442	NA
Die	627	NA
Other	168	NA
Total	1,440	NA
Grand total	8,580	NA

p/ Preliminary. r/ Revised. NA Not available.

1/ Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

2/ Data are rounded to three significant digits; may not add to totals shown.

Source: U.S. Department of Commerce.

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TABLE 8
U.S. EXPORTS OF ALUMINUM, BY COUNTRY 1/

Country or territory	Metals and alloys, crude		Plates, sheets, bars, etc. 2/		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
Armenia	--	--	--	--	--	--	--	--
Brazil	92	$241	18,400	$82,300	331	$618	18,800	$83,100
Canada	122,000	211,000	377,000	1,070,000	50,800	58,900	550,000	1,340,000
France	67	275	6,790	30,700	458	675	7,310	31,600
Georgia	--	--	--	--	--	--	--	--
Germany	320	1,030	12,500	40,500	277	1,010	13,100	42,500
Hong Kong	2,890	5,640	13,300	45,500	75,800	114,000	92,000	165,000
Italy	626	1,290	2,270	12,200	455	736	3,350	14,200
Japan	135,000	248,000	26,700	127,000	134,000	194,000	296,000	569,000
Korea, Republic of	36,900	74,600	29,400	126,000	29,400	40,400	95,700	241,000
Latvia	--	--	--	--	--	--	--	--
Mexico	33,200	68,800	101,000	314,000	14,700	20,100	149,000	403,000
Netherlands	294	701	1,410	8,990	345	648	2,050	10,300
Philippines	2,840	6,170	594	2,830	121	159	3,560	9,160
Russia	(3/)	4	86	443	1	14	87	461
Saudi Arabia	10	8	27,100	72,400	11	20	27,100	72,400
Singapore	171	509	4,500	38,500	389	780	5,060	39,800
South Africa	12	64	302	1,340	--	--	313	1,400
Taiwan	11,900	23,000	34,400	108,000	61,800	75,600	108,000	207,000
Thailand	16,200	33,300	9,980	27,800	4,520	9,540	30,700	70,600
Turkmenistan	--	--	(3/)	3	--	--	(3/)	3
Ukraine	--	--	1	6	--	--	1	6
United Kingdom	449	1,620	23,500	89,600	2,850	5,000	26,800	96,200
Uzbekistan	--	--	3	6	--	--	3	6
Venezuela	40	214	17,100	58,000	452	700	17,600	58,900
Other	6,070 r/	14,600 r/	105,000	358,000 r/	52,900	65,900	164,000	438,000
Total	369,000	690,000	812,000	2,620,000	430,000	588,000	1,610,000	3,900,000
1996:								
Armenia	--	--	23	99	--	--	23	99
Brazil	101	380	22,500	77,100	129	156	22,800	77,700
Canada	131,000	191,000	352,000	955,000	61,500	63,400	544,000	1,210,000
France	418	1,810	4,070	23,300	24	55	4,510	25,100
Georgia	--	--	7	47	--	--	7	47
Germany	343	1,170	21,900	30,600	190	216	22,400	31,900
Hong Kong	3,170	6,100	13,200	40,500	41,600	52,800	57,900	99,400
Italy	35	325	3,280	16,400	80	79	3,390	16,800
Japan	188,000	307,000	30,400	168,000	54,900	67,600	273,000	543,000
Korea, Republic of	20,500	36,200	22,000	93,200	37,800	42,400	80,200	172,000
Latvia	--	--	33	14	--	--	33	14
Mexico	48,000	80,400	105,000	333,000	17,100	21,300	170,000	435,000
Netherlands	410	432	1,710	8,740	375	458	2,500	9,630
Philippines	1,280	2,130	1,220	6,510	179	123	2,680	8,770
Russia	15	274	1	12	--	--	16	286
Saudi Arabia	32	40	18,900	53,900	--	--	18,900	53,900
Singapore	205	873	3,170	12,300	14	18	3,390	13,200
South Africa	13	105	1,500	5,520	--	--	1,520	5,620
Taiwan	8,650	14,800	12,800	45,700	48,200	42,100	69,600	103,000
Thailand	6,300	11,000	4,680	15,100	868	1,310	11,800	27,500
Turkmenistan	--	--	--	--	--	--	--	--
Ukraine	--	--	1	19	--	--	1	19
United Kingdom	706	4,550	18,300	86,700	12,700	17,400	31,700	109,000
Uzbekistan	--	--	--	--	--	--	--	--
Venezuela	46	173	11,600	33,600	418	424	12,100	34,200
Other	8,120	22,600	111,000	382,000	44,300	45,200	164,000	450,000
Total	417,000	682,000	760,000	2,390,000	320,000	355,000	1,500,000	3,420,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes castings, forgings, and unclassified semifabricated forms.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 9
U.S. EXPORTS OF ALUMINUM, BY CLASS 1/

Class	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	369,000	$690,000	417,000	$682,000
Scrap	430,000	588,000	320,000	355,000
Plates, sheets, bars, strip, etc.	764,000	2,380,000	703,000	2,130,000
Castings and forgings	6,630	81,900	12,200	105,000
Semifabricated forms, n.e.c.	40,700	157,000	44,800	147,000
Total	1,610,000	3,900,000	1,500,000	3,420,000
Manufactures:				
Foil and leaf	82,600	224,000	99,700	274,000
Powders and flakes	6,130	27,500	6,340	30,800
Wire and cable	43,600	135,000	28,500	104,000
Total	132,000	386,000	134,000	410,000
Grand total	1,740,000	4,280,000	1,630,000	3,830,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY CLASS 1/

Class	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	1,930,000	$3,690,000	1,910,000	$3,040,000
Plates, sheets, strip, etc., n.e.c. 2/	497,000	1,290,000	428,000	1,050,000
Pipes, tubes, etc.	9,080	52,300	11,300	54,300
Rods and bars	116,000	301,000	59,300	179,000
Scrap	419,000	562,000	402,000	460,000
Total	2,970,000	5,890,000	2,810,000	4,790,000
Manufactures:				
Foil and leaf 3/	46,800	177,000	57,100	207,000
Flakes and powders	1,450	6,140	1,840	5,920
Wire	39,700	89,800	76,900	148,000
Total	88,000	273,000	136,000	361,000
Grand total	3,060,000	6,170,000	2,940,000	5,150,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes plates, sheets, circles, and disks.
3/ Excludes etched capacitor foil.

Source: Bureau of the Census.

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TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY 1/

Country	Metals and alloys, crude		Plates, sheets, bars, etc. 2/		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
Argentina	--	--	97	$347	1,730	$2,610	1,820	$2,960
Australia	1,120	$3,380	2,070	5,610	931	1,500	4,120	10,500
Bahrain	--	--	8,690	21,200	93	125	8,780	21,300
Belgium	10	46	4,700	14,700	143	167	4,850	14,900
Brazil	87,800	162,000	2,250	5,540	1,210	1,840	91,300	170,000
Canada	1,290,000	2,510,000	304,000	757,000	219,000	312,000	1,810,000	3,580,000
Estonia	2,290	4,390	--	--	--	--	2,290	4,390
France	2,350	8,950	13,300	53,800	1,490	1,780	17,100	64,600
Germany	2,670 r/	7,630 r/	25,000	99,600	7,140 r/	11,900 r/	34,800	119,000
Italy	35	2,030	7,870	27,900	(3/)	2	7,910	30,000
Japan	237	901	10,400	47,500	719	622	11,400	49,000
Kazakstan	3,020	4,800	--	--	--	--	3,020	4,800
Mexico	2,230	3,290	11,700	31,700	107,000	130,000	121,000	165,000
Netherlands	744	1,170	4,780	17,600	911	1,380	6,430	20,100
Norway	204	1,410	265	899	163	195	632	2,500
Russia	396,000	719,000	124,000	260,000	10,700	18,700	531,000	997,000
Slovenia	--	--	3,770	13,600	--	--	3,770	13,600
South Africa	71	362	2,940	7,110	150	127	3,170	7,600
Spain	2,590	4,350	25,900	63,700	--	--	28,500	68,100
Tajikistan	19,700	31,800	--	--	142	184	19,800	32,000
Ukraine	41	59	--	--	--	--	41	59
United Arab Emirates	292	545	--	--	890	1,400	1,180	1,940
United Kingdom	2,750	4,550	14,200	49,200	8,370	11,500	25,300	65,200
Venezuela	102,000	177,000	34,600	78,800	26,200	28,300	163,000	284,000
Other r/	20,200	39,500	20,800	90,700	32,900	37,000	74,000	167,000
Total	1,930,000	3,690,000	622,000	1,650,000	419,000	562,000	2,970,000	5,890,000
1996:								
Argentina	1,450	2,270	1,030	2,660	3,060	3,490	5,540	8,420
Australia	1,080	1,840	1,660	4,470	1,310	1,300	4,050	7,610
Bahrain	--	--	8,930	20,200	--	--	8,930	20,200
Belgium	931	1,620	5,560	15,200	80	102	6,570	17,000
Brazil	11,700	18,400	436	1,110	415	515	12,500	20,100
Canada	1,340,000	2,210,000	296,000	674,000	223,000	265,000	1,850,000	3,150,000
Estonia	--	--	--	--	--	--	--	--
France	1,040	7,130	8,480	35,100	3,950	3,740	13,500	46,000
Germany	1,100	5,080	26,700	112,000	7,840	10,900	35,700	128,000
Italy	25	1,520	9,550	30,700	62	46	9,630	32,200
Japan	353	1,130	10,300	41,700	280	466	11,000	43,300
Kazakstan	18	226	--	--	--	--	18	226
Mexico	953	1,470	13,300	35,300	73,700	80,600	88,000	117,000
Netherlands	410	766	4,640	15,200	743	962	5,790	16,900
Norway	511	1,660	3,650	7,570	--	--	4,160	9,230
Russia	402,000	559,000	11,200	21,800	9,750	11,800	423,000	593,000
Slovenia	--	--	3,510	10,900	--	--	3,510	10,900
South Africa	2,310	3,870	3,240	7,400	204	230	5,750	11,500
Spain	120	173	19,100	42,100	6	22	19,200	42,300
Tajikistan	20,000	27,400	--	--	--	--	20,000	27,400
Ukraine	4,300	5,030	8	36	--	--	4,300	5,070
United Arab Emirates	--	--	--	--	1,920	2,160	1,920	2,160
United Kingdom	2,130	2,470	18,000	66,900	13,100	15,100	33,200	84,500
Venezuela	116,000	181,000	29,700	56,600	23,600	23,700	169,000	261,000
Other	6,330	8,600	23,000	85,700	38,300	39,900	67,600	134,000
Total	1,910,000	3,040,000	498,000	1,290,000	402,000	460,000	2,810,000	4,790,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes circles, disks, rods, pipes, tubes, etc.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 12
ALUMINUM, PRIMARY: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Argentina	156 r/	171 r/	176 r/	184 r/	185
Australia	1,236	1,381	1,317	1,297	1,372 3/
Austria	33	--	--	--	--
Azerbaijan e/	25	20	15	10	10
Bahrain	292	448	447	451	450
Bosnia and Herzegovina e/ 4/	30	15	10	10	10
Brazil	1,193	1,172	1,185	1,188	1,190
Cameroon e/	83	87	89 r/ 3/	80	80
Canada	1,972	2,308	2,255	2,172	2,282
China e/	1,100	1,220	1,450	1,870 r/	1,780
Croatia 4/	20	26	26 r/	31 r/	30
Czechoslovakia e/ 5/ 6/	68	XX	XX	XX	XX
Egypt	178	178	188	190 e/	190
France	418	426	384 r/	365 r/	365
Germany	603	552	505	575 r/	577
Ghana	180	175	141	135	137
Greece	153	148	144	131 r/	130
Hungary	27	28	31	25 e/	25
Iceland 7/	89	94	99	100	104 3/
India 6/	496	466	472	528 r/	518
Indonesia 6/	173	206	222	220 e/	225
Iran	117	109	116 e/	118 e/	118
Italy	161	156	176	178 r/	185 3/
Japan 8/	19	18	17	18	17
Mexico 6/	25	--	--	10	11
Netherlands	227 r/	232	219	216 r/	226 3/
New Zealand	243	277	271	273	284
Norway	838 r/	887	858	847	874 3/
Poland 9/	44	47	50	56 r/	52
Romania 10/	112	116	119 r/	142 r/	140
Russia	2,700	2,820	2,670	2,722	2,800
Serbia and Montenegro 4/	67	26	7	17 r/	36
Slovakia e/ 6/ 11/	XX	60	60	60	50
Slovenia e/ 4/	85 3/	80	80	80	70
South Africa	173	175	172	210 r/	620
Spain	359	356	338	362 r/	362 3/
Suriname e/	32	30	32 r/	32 r/	32
Sweden	103 r/	82	84 r/	95 r/	98 3/
Switzerland	52	36	24	21 r/	27
Tajikistan e/	400	250	235 3/	230 3/	198
Turkey	59	59	60	62 r/	60
Ukraine e/	100 r/	100 r/	100 r/	98 r/ 3/	88
United Arab Emirates: Dubai	245	242	247	240 e/	245
United Kingdom	244	239	231	238 r/	240 3/
United States	4,042	3,695	3,299	3,375	3,577 3/
Venezuela	561	568	585	630	600
Total	19,500	19,800	19,200	19,900 r/	20,700

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Primary aluminum is defined as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through May 12, 1997.

3/ Reported figure.

4/ Primary ingot plus secondary ingot.

5/ Dissolved Dec. 31, 1992. All production for Czechoslovakia in 1992 came from Slovakia.

6/ Primary ingot.

7/ Ingot and rolling billet production.

8/ Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1992--19,600; 1993--20,300; 1994--23,800; 1995--28,400; and 1996--28,000 (estimated).

9/ Primary unalloyed ingot plus secondary unalloyed ingot.

10/ Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

11/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

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ANTIMONY

By James F. Carlin, Jr.

Domestic primary smelter production increased moderately in 1996, but consumption of primary antimony declined slightly. The antimony price declined sharply during the year, ending at approximately the same price that prevailed before the precipitous price rise that occurred in 1994.

The estimated value of primary antimony metal and oxide produced in 1996 was $100 million. The estimated distribution of primary antimony uses in the United States was as follows: flame-retardants, 62%; transportation, including batteries, 15%; chemicals, 10%; ceramics and glass, 8%; and other, 5%. *(See tables 2, 3, and 4.)*

A small amount of antimony was recovered as a byproduct of the smelting of domestic lead and silver-copper ores, but almost all primary antimony metal and oxide produced domestically originated from imports.

Primary antimony metal and oxide were produced by six companies operating six plants using domestic and foreign feed material. Two plants were in Texas, and one each in Idaho, Montana, Nebraska, and New Jersey. Most domestic antimony smelting consisted of upgrading imported antimony trioxide to a higher purity.

Nearly all domestic secondary antimony was recovered at secondary lead smelters from recycled lead-acid batteries. A review of U. S. Geological Survey (USGS) data showed that recovery of secondary antimony had been overstated in the 1994 and earlier Annual Reviews. Accordingly, the revised figures for secondary production in table 1 are markedly lower than shown heretofore. Recycling and domestic mine output supplied less than one-half of the estimated domestic demand for antimony.

Antimony was mined as a principal product and produced as a byproduct of the smelting of base metal ores in 17 countries. It was estimated that China alone accounted for more than three-fourths of world mine production. Bolivia, China, Russia, and South Africa together accounted for about 91% of world mine production. Identified world antimony reserves at yearend 1996 were estimated to be 4.2 million metric tons.

Legislation and Government Programs

Sales of antimony from the National Defense Stockpile (NDS) proceeded for the fourth consecutive year. Sales were conducted on a negotiated bid basis and were held by the Defense Logistics Agency on the second Tuesday of each month. There was no maximum quantity that a company could bid on; however, there was a minimum of 4.5 metric tons (10,000 pounds) for each transaction. The material offered was Grade A and B ingots or cakes. Beginning in November 1996, broken pieces of Grade A material and antimony sulfide ore also were offered. In calendar year 1996, a total of 4,299 tons was sold. At yearend 1996, the antimony inventory in the NDS was 23,190 tons. Antimony is stockpiled in Government warehouses at 13 locations, with the Somerville, NJ, depot holding the largest amount.

Production

Mine Production.—In the Coeur d'Alene District of Idaho, Sunshine Mining Co., the sole domestic producer, recovered antimony as a byproduct of the treatment of complex silver-copper-antimony sulfide ore. The company responded to the USGS voluntary canvass request.

Smelter Production.—The domestic producers of primary antimony metal and oxide products were ASARCO Incorporated, Omaha, NE; Amspec Chemical Corp., Gloucester City, NJ; Anzon Inc., Laredo, TX; Laurel Industries Inc., La Porte, TX; Sunshine Mining Co., Kellogg, ID; and U.S. Antimony Corp., Thompson Falls, MT. All six primary smelters replied voluntarily to the USGS request for production data.

Old scrap, predominantly lead battery plates, was the source of almost all of the secondary antimony output. New scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. Antimonial lead was the main market for scrap antimony.

Consumption

Domestic consumption of primary antimony declined slightly in 1996. Antimonial lead registered the sharpest relative decline. Lead-antimony alloys were used in automotive vehicle batteries, ammunition, corrosion-resistant pumps and pipes, tank linings, roofing sheets, solder, cable sheaths, and antifriction bearings. Antimony compounds were used in plastics as stabilizers and as flame retardants. Antimony trioxide, often immersed in an organic solvent, was used to enhance the flame retardant properties of plastics, textiles, and other combustibles. Antimony was used as a decolorizing and refining agent in some forms of glass, such as optical glass.

Of the 177 companies to which a voluntary USGS canvass form was sent, 153 firms responded; consumption data for 24 firms were estimated.

Prices

In 1996, antimony metal prices continued the downward drift that had started in 1995, declining from the peak price established in late 1994, climaxing the dramatic surge in prices that began in the spring of 1994. The major cause of the

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1994-95 price increase may have been the extensive flooding in the major antimony mining regions in China, which caused interruptions in production and delays in shipping. Those disruptions eased by late 1995, and normalcy returned by 1996. Thus, prices drifted steadily downward in 1996 toward normal historical levels.

The New York dealers' antimony metal price, published by Platt's Metals Week, averaged $1.47 per pound for the year, compared with $2.28 per pound in 1995. The price range for high-tint antimony trioxide, published by American Metal Market, was $2.30 to $2.45 at the beginning of the year and finished the year at $1.25 to $1.30 per pound.

Foreign Trade

Imports of antimony metal increased somewhat in 1996. China supplied about 74% of the antimony metal imports. Imports of antimony oxide also increased somewhat in 1996, with China supplying about 42% of the imports. *(See tables 5, 6, 7, and 8.)*

Outlook

Domestic antimony demand declined slightly in 1996. The decline occurred in a year in which antimony prices declined sharply, and the softening of domestic consumption perhaps contributed to the price decline. Use in the major domestic consumption category, flame retardants, rose moderately. It is believed that the flame retardant market is likely to remain strong from some years.

It is anticipated that the reliance of the United States on imported antimony materials will continue, with China's dominance as a supplier of antimony continuing.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Antimony. Ch. in Minerals Commodity Summaries, annual.[1]

Antimony. Ch. in Minerals Yearbook, annual.[1]

Antimony. Ch. in United States mineral resources, U.S.Geological Survey Professional Paper 820.

Antimony. Mineral Industry Surveys, quarterly.[1]

Other

American Metal Market, daily.

Antimony. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines, Bulletin 675, 1985.

Engineering and Mining Journal.

Metal Bulletin (London).

Platt's Metals Week.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT ANTIMONY STATISTICS 1/

(Metric tons of antimony content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production:					
Primary:					
Mine (recoverable antimony) 2/	360	266	215	262	242
Smelter	20,100	22,000	25,500	23,500	25,700
Secondary 3/	12,700 r/	9,620 r/	12,200 r/	10,500	7,900
Exports of metal, alloys, waste and scrap	947	315	1,350	1,610	462
Exports of antimony oxide 4/	4,820	3,900	6,500	6,590	3,990
Imports for consumption	31,200	30,900	41,500	36,600	37,600
Reported industrial consumption, primary antimony	12,200	12,400	14,800	14,300	13,600
Stocks: Primary antimony, all classes, Dec. 31	8,740	9,080	10,900	10,600	11,200
Price: Average, cents per pound 5/	79.0	76.9	177.7	227.8	146.5
World: Mine production	90,100 r/	87,800	117,000 r/	154,000 r/	126,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Data from 10-K reports.

3/ A review of secondary lead smelting, the source of nearly all secondary antimony, showed that recovery of secondary antimony had been markedly overstated in the 1994 and earlier annual reviews.

4/ Antimony content is calculated by the U.S. Geological Survey.

5/ New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.

TABLE 2
REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY ANTIMONY
IN THE UNITED STATES 1/

(Metric tons of antimony content)

	Class of material consumed			
Year	Metal	Oxide	Other 2/	Total
1995	2,850	11,400	106	14,300
1996	2,060	11,400	131	13,600

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes sulfide and residues.

TABLE 3
REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY
ANTIMONY IN THE UNITED STATES, BY PRODUCT 1/

(Metric tons of antimony content)

Product	1995	1996
Metal products:		
Antimonial lead	2,230	1,760
Bearing metal and bearings	53	44
Solder	192	255
Other 2/	1,290	1,050
Total	3,760	3,110
Nonmetal products:		
Ammunition primers	19	17
Ceramics and glass	1,080	1,030
Pigments	492	450
Plastics	1,090	1,080
Other 3/	85	115
Total	2,770	2,690
Flame-retardants:		
Adhesives	263	248
Plastics	6,690 r/	6,830
Rubber	443	403
Textiles	379	275
Other 4/	23 r/	5
Total	7,800 r/	7,770
Grand total	14,300	13,600

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes ammunition, cable covering, castings, sheet and pipe, and type metal.

3/ Includes fireworks and rubber products.

4/ Includes paper and pigments.

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TABLE 4
INDUSTRY STOCKS OF PRIMARY ANTIMONY
IN THE UNITED STATES, DECEMBER 31 1/

(Metric tons of antimony content)

Type of material	1995	1996
Metal	2,450	3,480
Oxide	4,450	4,330
Other 2/	3,680	3,360
Total	10,600	11,200

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes ore and concentrate, sulfide and residues.

TABLE 5
U.S. EXPORTS OF ANTIMONY METAL, ALLOYS, AND
WASTE AND SCRAP, BY COUNTRY 1/

	1995		1996	
Country	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Canada	178	$482	147	$392
Mexico	672	994	240	945
Netherlands	162	569	--	--
Spain	209	994	--	--
Taiwan	138	1,090	1	7
United Kingdom	112	164	(2/)	(2/)
Other	140	718	73	420
Total	1,610	5,010	462	1,760

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 6
U.S. EXPORTS OF ANTIMONY OXIDE, BY COUNTRY 1/

	1995			1996		
Country	Gross weight (metric tons)	Antimony content 2/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Antimony content 2/ (metric tons)	Value (thousands)
Australia	54	45	$216	60	50	$211
Brazil	572	475	578	162	134	647
Canada	1,890	1,570	6,140	1,420	1,180	5,400
Colombia	436	362	730	120	100	584
Germany	12	10	63	98	81	430
Indonesia	192	159	303	10	8	55
Italy	254	211	633	171	142	649
Japan	1,050	873	2,600	852	707	2,300
Korea, Republic of	153	127	502	172	143	755
Mexico	875	726	1,860	274	227	1,590
Netherlands	18	15	60	26	22	69
Singapore	735	610	1,980	589	489	2,040
Taiwan	885	735	1,320	411	341	1,580
Turkey	95	79	265	50	42	337
United Kingdom	358	297	1,740	154	128	703
Other	361	299	965	239	198	1,210
Total	7,940	6,590	19,900	4,810	3,990	18,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Antimony content is calculated by the U.S. Geological Survey.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY, BY CLASS AND COUNTRY 1/

Country	1995 Gross weight (metric tons)	1995 Antimony content 2/ (metric tons)	1995 Value (thousands)	1996 Gross weight (metric tons)	1996 Antimony content 2/ (metric tons)	1996 Value (thousands)
Antimony ore and concentrate:						
Australia	245	201	$403	8	5	$49
Bolivia	2,500	2,050	11,000	270	221	336
Canada	1,550	481	1,140	542	144	415
China	1,260	1,060	3,920	511	473	1,190
Kyrgyzstan	278	228	1,210	--	--	--
Other	306 r/	231 r/	636 r/	282	159	890
Total	6,140	4,260	18,300	1,610	1,000	2,880
Antimony oxide:						
Belgium	1,120	926	6,270	1,300	1,080	5,620
Bolivia	2,080	1,720	5,650	2,990	2,480	8,710
China	6,780	5,630	26,900	9,310	7,730	27,400
France	240	199	1,520	259	215	1,020
Germany	183	152	3,120	--	--	--
Guatemala	--	--	--	220	183	729
Hong Kong	170	141	834	253	210	887
Kyrgyzstan	753	625	2,630	180	150	424
Mexico	3,720	3,080	1,700	3,800	3,150	6,850
South Africa	3,180	2,640	886	3,440	2,860	870
United Kingdom	133	110	947	181	150	718
Other	225	188	1,390	172	143	997
Total	18,600	15,400	51,800	22,100	18,300	54,200

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Antimony ore and concentrate content reported by Bureau of the Census. Antimony oxide content is calculated by the U.S. Geological Survey.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY METAL, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Bolivia	255	$1,010	153	$424
Canada	120	371	128	338
Chile	20	78	5	36
China	12,100	50,600	13,500	38,000
Hong Kong	841	2,250	1,620	4,710
Kyrgyzstan	1,880	4,050	1,240	4,040
Japan	23	942	24	1,090
Mexico	1,630	1,180	1,330	1,030
Thailand	20	64	119	387
United Kingdom	20	251	58	304
Other	1	168	88	530
Total	16,900	60,900	18,300	50,900

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 9
ANTIMONY: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Australia 3/	1,701	1,700 e/	1,700 e/	900 r/	1,300 4/
Bolivia	6,022	5,556	7,050	6,426 r/	6,600
Canada 5/	948	673	750	574 r/	1,405 p/
China e/	59,000 r/	60,000	91,000 r/	125,000 r/	98,000
Czech Republic e/ 6/	XX	250	--	--	--
Czechoslovakia e/ 7/	1,000	XX	XX	XX	XX
Guatemala e/	582 4/	600	600	610	610
Honduras	--	--	--	4,800	4,800
Kyrgyzstan e/	3,000	2,500	2,000 r/	1,500 r/	1,200
Mexico 8/	1,200 e/	1,469	267 r/	-- r/	-- 4/
Morocco 5/	197	180	175	-- r/	--
Namibia (content of sodium antimonate)	6	8	29	-- e/	--
Pakistan e/	12	--	--	6 4/	5
Peru (recoverable)	339	240	460 e/	460 e/	460
Russia (recoverable) e/	10,000	8,000	6,000 r/	6,000 r/	6,000
Slovakia e/ 6/	XX	450	400	400	300
South Africa 5/	3,779	4,111	4,534	5,537 r/	4,800
Tajikistan e/	1,500	1,200	1,000	1,000	500
Thailand (content of ore and concentrate) e/	270	620	500	230 r/	250
Turkey	309	111	75	100 e/	100
United States	W	W	W	W	W
Zimbabwe 5/	254	95	65	37 r/	50
Total	90,100 r/	87,800	117,000 r/	154,000 r/	126,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." XX Not applicable

1/ World totals and estimated data have been rounded to three significant digits; may not add to totals shown.

2/ Antimony content of ore unless otherwise indicated. Table includes data available through June 10, 1997.

3/ Antimony content of antimony ore and concentrate, lead concentrates, and lead-zinc concentrates.

4/ Reported figure.

5/ Antimony content of concentrate.

6/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

7/ Dissolved Dec. 31, 1992.

8/ Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.

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ARSENIC

By Daniel L. Edelstein

The United States was the world's largest consumer of arsenic in 1996, accounting for about two-thirds of world demand. Domestic apparent demand for arsenic metal and compounds has remained relatively stable over the past 4 years, averaging about 2,000 metric tons of contained arsenic per year. All domestic arsenic requirements were met by imports; arsenic production in the United States was last reported in 1985. On a contained metal basis, arsenic trioxide accounted for 99% of imports in 1996. China, the world's largest producer of both arsenic trioxide and arsenic metal, was the leading source of U.S. imports of both products. Including material shipped through Hong Kong, China accounted for 44% and 84%, respectively, of trioxide and metal imports.

Legislation and Government Programs

Because of the toxicity of arsenic and its compounds, several environmental and workplace regulations proposed or amended during 1996 specify limitations for arsenic releases or exposure levels. In May, the Environmental Protection Agency (EPA) issued rules that raised the minimum level of substance release that requires public notification for 202 substances under the Community Right-to-Know Act of 1986, for its list of extremely hazardous substances (EHS); the list includes four arsenic compounds. However, the reportable quantities for these compounds remained unchanged at the minimum 1 pound per occurrence (U.S. Environmental Protection Agency, 1996b). In July, EPA proposed adding seven groups to the list of industry groups subject to the reporting requirements of the Community Right-to-Know Act, including coal mining, metal mining, and electric utilities. Arsenic compounds were cited as contaminants in coal and oil combustion products at electric powerplants (U.S. Environmental Protection Agency, 1996a).

In July, the Occupational Safety and Health Administration (OSHA), as part of a Presidential directive to remove or revise standards that are out of date, duplicative, or not needed to maintain employee health and safety, proposed revision of medical surveillance requirements for certain workers exposed to inorganic arsenic, including elimination of the semiannual sputum cytology examinations and reduction from semiannual to annual the frequency of required chest x-rays for workers 45 years of age or older or workers having had 10 or more years of exposure to arsenic at levels above the action level. In reevaluating the sputum-cytology provision, OSHA found no studies that addressed the efficacy of this test as a screening tool for lung cancer for employees specifically exposed to inorganic arsenic. Similarly, the efficacy of providing semiannual chest x-rays as a screening tool had not been established (U.S. Department of Labor, 1996).

Consumption

Overall consumption of arsenic remained relatively unchanged in 1996, for the third consecutive year. Estimated demand for arsenic in wood preservatives, which accounted for about 90% of total arsenic demand, was essentially unchanged from that of 1995, despite growth in the domestic housing industry; housing starts and construction spending rose by about 9% and 4%, respectively. Demand for arsenic by wood preservative formulators in 1995 had been boosted by in-process construction and restocking by distributors of pressure-treated lumber following the 1994 surge in housing. Arsenic trioxide was consumed in the production of arsenic acid for formulation of chromated copper arsenate (CCA) wood preservatives by the three principal producers of arsenical wood preservatives: Hickson Corp., Conley, GA; CSI, Harrisburg, NC; and Osmose Corp., Memphis, TN. Osmose also produces arsenic acid for the glass industry as a fining agent to disperse air bubbles.

The demand for arsenic metal for nonferrous alloys especially battery-lead alloys, plummeted for the second consecutive year. Consumers, fearing disruption from Chinese suppliers, may have over-brought in 1994, reducing their need for metal purchases in the 2 subsequent years. Some of the surplus metal inventories may have been exported in 1995, accounting for a rise in metal exports. Also, continued growth in market share for maintenance-free automotive batteries, which require little or no arsenic, may be further lowering demand for arsenic metal. Commercial grade arsenic metal 99% pure, is used in lead- and copper-based alloys as a minor additive (0.01% to 0.5%) to increase strength in the posts and grids of lead-acid storage batteries and to improve corrosion resistance and tensile strength in copper alloys. About 15 tons of high-purity arsenic metal, of 99.9999% or higher purity, was used in the manufacture of crystalline gallium arsenide, a semiconducting material used in optoelectronic circuitry, high-speed computers, and other electronic devices.

Arsenic consumed in agricultural uses continued to decline following the EPA's 1993 cancellation of arsenic acid for use as a cotton desiccant. The remaining agricultural use for arsenic was as an herbicide for control of weeds. ISK Bioscience, Mentor, OH, produced the arsenical herbicide monosodium methanearsonate (MSMA) at a plant in Houston, TX.

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Prices

Prices for arsenic trioxide are not published. The average customs value for imported arsenic trioxide in 1996 was 22 cents per pound, down by about 2 cents per pound from that of 1995. The decline was attributed mostly to the lower value of some off-grade material imported from Chile for blending with high-purity material. High-purity trioxide from Mexico averaged 33 cents per pound. Prices for high-grade (minimum 99%) arsenic trioxide generally are quoted at an 8- to 12-cent-per-pound premium to low-grade (minimum 95%) arsenic trioxide. Owing to lowered demand and surplus supplies, prices for arsenic metal declined sharply, the Chinese import price averaging 40 cents per pound, down almost 40% from that of 1995.

World Review

Commercial-grade arsenic trioxide was recovered from the smelting or roasting of nonferrous metal ores or concentrates in at least 18 countries. High-arsenic smelter or roaster dusts and residues that usually are not processed to commercial-grade trioxide are recovered in several other countries as well as at plants in countries producing commercial-grade material. This material is frequently stockpiled and could be available for future processing. Ghana is one such country that has the estimated capacity to produce about 9,000 tons per year of crude trioxide from gold roasting operations. Most countries do not report their arsenic production, and world production values have a high degree of uncertainty. China was the world's largest producer as well as the major source of U.S. imports. Chinese production was estimated to have declined sharply in 1996 owing to the combined impact of environmental constraints, treatment of lower arsenic content ores, and weather-related problems. In France, Societe d'Exploitation Pyrometalurgie Salsigne, formed in November 1992, began commercial production of arsenic trioxide in 1993. The company which purchased the gold smelter and roaster formerly operated by Mines et Products Chimiques de Salsigne, has the capacity to produce significant quantities of refined arsenic trioxide. However, the company faced financial difficulties in 1995 and had filed for bankruptcy. Production had been halted by yearend 1995, and the plant remained idle throughout 1996. A second producer, Metaleurop SA, with capacity to produce about 6,000 tons per year of high purity trioxide, reportedly processed some imported crude trioxide from Ghana.

In Chile, production from the roasting of gold-copper ores at the El Indio Mine increased in 1996, countering the decline in Chinese production. U.S. imports from Chile rose more than 270%, making it the second largest source for domestic imports of arsenic trioxide. Included in both imports and production from Chile in 1996 were an estimated 2,000 tons of stockpiled off-grade material, not previously counted as production, that was imported for blending with high-grade trioxide.

Arsenic metal, which accounts for only 3% of world demand for arsenic, was produced by the reduction of arsenic trioxide. Commercial-grade arsenic metal, 99% pure, accounted for the majority of world arsenic metal production and was produced only in China. High-purity arsenic, 99.9999% pure or greater, for use in the semiconductor industry was produced by about 10 companies. Furukawa Electric Co. Ltd. in Japan and Preussag AG in Germany were believed to be the world's largest producers, with capacities of 30 and 15 metric tons per year, respectively.

Outlook

With the major market for arsenic being the production of arsenical wood preservatives, the demand for arsenic is closely tied to the home construction market, where wooden decks containing arsenical preservatives have become ubiquitous. According to data published by the American Wood Preservative Institute, demand for treated wood rose precipitously in the 5-year period ending in 1988. In 1988, about 450 million cubic feet of wood were treated with waterborne preservatives (98% estimated to be CCA), compared with 300 million cubic feet in 1984. Demand softened in the 1989-91 period before resuming its upward trend. In 1995, the last year for which data are available, the quantity of wood treated with waterborne preservatives, was about 450 million cubic feet, down from about 500 million in 1994. In 1995, waterborne preservatives were used for about 75% of all treated lumber.

The apparent demand for arsenic trioxide in wood preservatives declined slightly in 1996 despite an increase in housing starts. Restocking by wood preservative manufacturers and carry-over from the 13% growth in housing starts in 1994 may have served to boost apparent demand in 1995. Future demand for arsenic is expected to closely follow that for new home construction, although the replacement and renovation markets could increase as a percentage of total market share. The prohibition on use of CCA preservatives in certain applications and the greater acceptance of alternative preservatives could negatively affect future demand.

Despite environmental regulation that has led to global dislocations of production over the past decade, including cessation of production in two historically large producing countries, Sweden and the United States, new suppliers have emerged to fill the voids. Although environmental pressures may continue to cause curtailment of existing capacity, given the abundance of high-arsenic residues from nonferrous metal processing, world supplies of arsenic trioxide are expected to remain adequate to meet projected need. Environmental regulation may, in fact, encourage commercial production from existing stockpiles of noncommercial material.

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TABLE 1
ARSENIC SUPPLY-DEMAND RELATIONSHIPS 1/

(Metric tons, arsenic content)

	1992	1993	1994	1995	1996
U.S. supply:					
Imports, metal	740	767	1,330	557	252
Imports, compounds	23,300	20,900	20,300	22,100	21,200
Total	24,000	21,600	21,600	22,700	21,400
Distribution of U.S. supply:					
Exports 2/	94	364	79	430	36
Apparent demand	23,900	21,300	21,500	22,300	21,400
Estimated U.S. demand pattern:					
Agricultural chemicals	3,900	3,000	1,200	1,000	950
Glass	900	900	700	700	700
Wood preservatives	17,900	16,200	18,000	19,600	19,200
Nonferrous alloys and electronics	800	800	1,300	600	250
Other	400	400	300	400	300
Total	23,900	21,300	21,500	22,300	21,400

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Metal only.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ARSENICALS 1/

	1995		1996	
Class and country	Quantity 2/ (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	786	$420	579	$314
Bolivia	--	--	120	55
Chile	3,210	1,260	8,790	2,930
China	15,900	8,230	11,000	5,650
France	2,820	1,550	2,480	1,360
Hong Kong	1,510	619	1,380	681
Mexico	3,560	2,560	2,980	2,140
Philippines	1,080	430	612	231
United Kingdom	1	2	--	--
Other	195	90	18	20
Total	29,000	15,200	28,000	13,400
Arsenic acid:				
Canada	--	--	(3/)	2
Israel	(3/)	3	1	13
Total	(3/)	3	1	14
Arsenic metal:				
China	491	709	212	185
Germany	37	2,000	10	2,110
Japan	29	1,400	29	1,480
United Kingdom	--	--	(3/)	23
Other	(3/)	3	--	--
Total	557	4,100	252	3,790

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data erroneously reported as "thousand metric tons."
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 3
AVERAGE ARSENIC PRICES

(Cents per pound)

	1995	1996
Trioxide, Mexican	33	33
Metal, Chinese	66	40

Source: Calculated from Bureau of the Census import data.

TABLE 4
ARSENIC TRIOXIDE: 1/ WORLD PRODUCTION, BY COUNTRY 2/ 3/

(Metric tons)

Country 4/	1992	1993	1994	1995	1996 e/
Belgium e/	2,000	2,000	2,000	2,000	2,000
Bolivia	633	663	341	362 r/	370
Canada e/	250	250	250	250	250
Chile e/	6,016 5/	6,200	6,300	6,400	9,000
China e/	15,000 r/	14,000 r/	18,000 r/	21,000 r/	15,000
France e/	2,000	3,000	6,000	5,000	3,000
Georgia e/	1,500	1,000	500	400	400
Germany e/	300	300	300	250 r/	250
Ghana e/ 6/	500	500	500	500	500
Iran e/	492 5/	500	500	500	500
Japan e/	50	40	40	40	40
Kazakstan e/	2,000	2,000	1,500	1,500	1,500
Mexico	4,293	4,447	4,400 e/	4,500 e/	4,300
Namibia 7/	2,456	2,290	3,047 r/	1,661 r/	1,100
Peru 8/	644 r/	391 r/	286 r/	285 r/ e/	285
Philippines e/	5,000	2,000	2,000	2,000	2,000
Portugal e/	150	150	150	100	100
Russia e/	2,500	2,000	1,500	1,500	1,500
Total	45,800 r/	41,700 r/	47,600 r/	48,200 r/	42,100

e/ Estimated. r/ Revised.

1/ Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.

2/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

3/ Table includes data available through Apr. 1, 1997.

4/ Austria, Hungary, the Republic of Korea, South Africa, Spain, the United Kingdom, and former Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make reliable estimates of output levels, if any.

5/ Reported figure.

6/ Estimated commercial byproduct of gold ore roasting. Does not include additional byproduct production of noncommercial grade material estimated at 4,000 tons in 1992, and up to 9,000 tons per year in 1993-96.

7/ Output of Tsumeb Corp. Ltd. only.

8/ Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.

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ASBESTOS

By Robert L. Virta

Asbestos is a generic name given to six fibrous minerals that have been used widely in commercial products. The six types of asbestos are chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. The most widely used variety is chrysotile. The properties that make asbestos so versatile and cost effective are high tensile strength, chemical and thermal stability, high flexibility, low electrical conductivity, and large surface area.

Legislation and Government Programs

The Occupational Safety and Health Administration issued a notice amending its asbestos standard covering general industry, construction, and the shipyard industry. The notice provided corrections and clarifications concerning respirator use, signs, training, medical surveillance, and limitations for Class III and Class IV work (U.S. Department of Labor, 1996).

A variety of asbestos-containing civilian products are used by the military. Examples include friction materials (brakes and clutches), gaskets, packings, asbestos-reinforced plastics, and roofing products for use on military vehicles, ships, rockets, missiles, and in military construction. Strategic-grade asbestos is not required in the manufacture of these products and classified applications which use strategic-grade asbestos are believed to be minimal. Consequently, the Department of Defense authorized the disposal of 9,767 metric tons of strategic- and nonstrategic-grade chrysotile; 30,849 tons of amosite; and 33 tons of crocidolite from the National Defense Stockpile.

Production

Chrysotile was the only variety of asbestos produced in the United States. It was mined in the United States by one company, KCAC Inc., in San Benito County, CA. KCAC operated a mine in a highly sheared serpentinite composed of matted, short fiber chrysotile and unfractured serpentinite (also called a mass fiber deposit). The ore was stripped and wet processing was used to beneficiate the fiber. Domestic production (sales) increased slightly to 9,550 tons. *(See table 1.)* Domestic production data for asbestos were collected by means of a voluntary survey of the one domestic mining operation, representing 100% of the sales data shown in table 1.

Consumption

U.S. consumption of asbestos remained essentially unchanged at 21,700 tons in 1996. The three leading domestic markets were friction products, packings, and roofing products with 33%, 12%, and 50% of the asbestos market, respectively.

More than 99% of the asbestos consumed domestically was chrysotile. The remainder was crocidolite. Ninety-four percent of the chrysotile consumed in the United States was grade 7, followed by grades 5, 6, 4, and 3. *(See table 2.)* Markets for crocidolite were very limited and consumption was estimated to be less than 5 tons despite reported imports of 197 tons.

Prices

The average unit value of domestically produced asbestos decreased slightly from that of 1995. Unit values for all varieties of imported asbestos ranged from $147 per ton to $2,274 per ton and averaged $226 per ton. Unit values for all varieties of exported asbestos ranged from $173 per ton to $4,883 per ton and averaged $345 per ton.

The customs unit value for imported chrysotile ranged from $147 per ton to $2,274 per ton. The average unit value for imported crude chrysotile was $1,717 per ton. The average unit values for spinning grade chrysotile and other chrysotile types were $277 per ton and $219 per ton, respectively. Higher unit values for chrysotile imports were associated with shipments of only a few tons or shipments of long-fiber chrysotile from Zimbabwe. The average unit value for imported crocidolite was reported to be $186 per ton. *(See table 3.)*

Approximate equivalents, in dollars per metric ton, of prices for Canadian chrysotile, f.o.b. mine, ranged between $315 per ton and $2,705 per ton, depending on the grade. Chrysotile from South Africa ranged from $200 per ton to $440 per ton. Crocidolite from South Africa ranged from $640 per ton to $920 per ton (Industrial Minerals, 1996b). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade

The value of asbestos fibers and asbestos products exported and reexported decreased 10% in 1996. Japan was the largest importer of unmanufactured asbestos fiber. Canada was the largest importer of unmanufactured fibers and manufactured products from the United States, followed by Mexico, and Japan. *(See table 4.)* The only increases in export value were observed for the manufactured asbestos fiber products and the clutch facings and linings categories. Exports and reexports of brake linings and disk pads accounted for 80% of the value of all manufactured asbestos products. *(See table 5.)*

Approximately 15,400 tons of asbestos were exported in 1996. The exports included asbestos crudes, fiber, stucco, sand,

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and refuse. It is likely that some manufactured asbestos products, nonasbestos fiber, and/or nonasbestos mineral exports also were included in the export total. Exports of processed asbestos fiber (excluding stucco, sand, etc.) were estimated to be less than 10,000 tons in 1996.

Canada supplied nearly all of the asbestos imported by the United States. Most of this asbestos fiber was chrysotile. *(See table 6.)* Approximately 197 tons of asbestos imports were reported as crocidolite in 1996. Based on the lack of any significant markets in the United States, most of the imports reported as crocidolite probably were chrysotile. Although Canada was listed as the source of crocidolite imports, the crocidolite was mined in South Africa and transshipped through Canada.

World Review

World production of asbestos was estimated to be 2.29 million tons. Russia continued to be the largest producer of asbestos, followed by Canada, China, Kazakstan, Brazil, and Zimbabwe. These countries accounted for 90% of the world production. *(See table 7.)* Turner and Newell PLC sold its share of its asbestos mines and mills in Zambia and Zimbabwe to Africa Resources. Africa Resources was established by Zimbabwean industrialists (Industrial Minerals, 1996c). The French Government issued a ban on the use of asbestos. The ban went into effect January 1, 1997 (Industrial Minerals, 1996a). In 1994, MDS of Germany agreed to invest $4.1 million in money or equipment in JSC Uralasbest in return for the right to purchase 15% of JSC Uralasbest. MDS, however, did not meet the terms of the agreement so an arbitration court decided that the 15% share of JSC Uralasbest would revert back to state ownership (Industrial Minerals in the CIS, 1996). JM Asbestos Inc. began development of an asbestos mine in Quebec. The mine will have an annual capacity of 250,000 tons. Partners in the development are Groupe Minier Asbestos-Estrie, an employees' cooperative, and Capital d'Amerique (North American Minerals News, 1996).

Outlook

Domestic asbestos consumption will decrease in response to opposition to its use in consumer goods and building products. The decrease should be much smaller than in previous years based on the large amount of substitution for asbestos that has already taken place within the U.S. manufacturing sector. A similar trend is expected to be followed for world production. Besides the health and environmental issues, economic problems have hampered production within the former Soviet Union, the leading producer of asbestos. Declines in world production of 4% to 7% per year can be expected based on the performance of the industry over the past 3 years.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT ASBESTOS STATISTICS 1/

(Metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Production (sales):						
Quantity		15,600	13,700	10,100	9,290	9,550
Value 2/	thousands	$6,140	$5,960	$5,120	W	W
Exports and reexports 3/ (unmanufactured):						
Value	thousands	$6,720	$8,440	$6,550	$6,010	$5,310
Exports and reexports of asbestos products:						
Value	thousands	$134,000	$141,000	$177,000	$180,000	$163,000
Imports for consumption 4/ (unmanufactured):						
Quantity		31,600	30,800	25,800	21,900	21,600
Value	thousands	$7,210	$6,960	$5,390	$4,810	$4,880
Consumption, apparent 5/		32,800	31,600	26,800	22,000	21,700
World: Production		3,350,000 r/	2,710,000 r/	2,510,000 r/	2,420,000 r/	2,290,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits.

2/ F.o.b. mine.

3/ F.a.s. value; includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.

4/ U.S. Customs declared value.

5/ Production, plus imports, minus producer exports of asbestos fiber, plus adjustments in Government and industry stocks.

TABLE 2
U.S. ASBESTOS CONSUMPTION BY END USE, GRADE, AND TYPE 1/ 2/

(Metric tons)

	Chrysotile							
End use	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Total	Crocidolite 3/	Total asbestos
1995	71	294	542	364	20,400	21,600	192	22,000 4/
1996:								
Coatings and compounds	--	--	--	--	245	245	--	245
Friction products	1	3	396	240	6,450	7,090	--	7,090
Packing	--	4	105	70	2,380	2,560	--	2,560
Paper	--	--	--	--	136	136	--	136
Plastics	40	1	--	--	--	41	--	41
Roofing products	--	2	--	--	10,800	10,800	--	10,800
Other	48	134	156	--	293	632	197	829
Total	89	145	657	310	20,300	21,500	197	21,700

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Estimated distribution based upon data provided by the Asbestos Institute, Montreal, Canada, and the U.S. Geological Survey asbestos producer survey.

3/ May include imports of chrysotile. Estimated consumption of crocidolite was less than 5 tons.

4/ Includes 162 tons for which the end use breakout is unknown.

TABLE 3
CUSTOMS UNIT VALUE OF IMPORTED ASBESTOS

(Dollars per metric ton)

	1995	1996
Canada:		
Chrysotile:		
Crude	232 r/	352
Spinning	235 r/	277
Other	203 r/	204
South Africa: Crocidolite 1/	196	186

r/ Revised.

1/ May include imports of chrysotile.

Source: Bureau of the Census.

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TABLE 4
U.S. EXPORTS AND REEXPORTS OF ASBESTOS FIBERS AND PRODUCTS 1/ 2/

(Thousand dollars)

Country	1995			1996		
	Unmanufactured fiber 3/	Manufactured products 4/	Total	Unmanufactured fiber 3/	Manufactured products 4/	Total
Australia	23	1,300	1,320	25	2,100	2,130
Brazil	229	463	692	589	1,250	1,840
Canada	152	98,100	98,200	102	93,500	93,600
Germany	--	3,190	3,190	--	2,130	2,130
Japan	3,370	4,820	8,200	3,300	6,130	9,440
Korea, Republic of	212	4,050	4,260	116	1,290	1,400
Kuwait	--	78	78	--	395	395
Mexico	750	17,300	18,000	707	14,300	15,000
Saudi Arabia	--	1,370	1,370	--	1,180	1,180
Thailand	22	193	215	11	362	373
Turkey	--	257	257	--	504	504
United Kingdom	9	2,830	2,840	9	3,780	3,790
Venezuela	--	5,700	5,700	--	1,660	1,660
Other	1,240	40,100	41,400	454	34,200	34,700
Total	6,010	180,000	186,000	5,310	163,000	168,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ F.A.S. value.
3/ Includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.
4/ Also includes products manufactured using asbestos substitutes.

Source: Bureau of the Census.

TABLE 5
U.S. EXPORTS AND REEXPORTS OF ASBESTOS AND ASBESTOS PRODUCTS 1/

	1995		1996	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Unmanufactured: Asbestos 3/	14,600	$6,010	15,400	$5,310
Manufactured:				
Asbestos fibers	NA	744	NA	905
Brake linings and disk brake pads 4/	NA	147,000	NA	130,000
Clutch facings and linings 5/	NA	8,450	NA	11,600
Clothing, cord, fabric, yarn	NA	1,520	NA	710
Gaskets, packing and seals	NA	3,870	NA	3,140
Panel, sheet, tile, tube 6/	NA	7,330	NA	6,840
Paper and millboard	NA	3,140	NA	2,620
Other articles 7/	NA	7,910	NA	7,120
Total	XX	180,000	XX	163,000

NA Not available. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ F.A.S. value.
3/ Includes crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.
4/ Includes asbestos and cellulose fiber brakes and similar materials.
5/ Includes clutches and other friction materials, excluding brakes and brake pads.
6/ Includes asbestos cement and cellulose fiber cement products.
7/ Includes asbestos and cellulose fiber products.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF ASBESTOS FIBERS, BY TYPE, ORIGIN, AND VALUE 1/ 2/

Type	Canada		Other		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:						
Chrysotile:						
Crude	20	$5	75	$167	95	$172
Spinning fibers	430	101	41	116	471	217
All other	19,100	3,770	46	84	19,200	3,850
Crocidolite (blue) 3/	192	38	--	--	192	38
Other (unspecified asbestos type)	2,010	530	--	--	2,010	530
Total	21,800	4,440	162	367	21,900	4,810
1996:						
Chrysotile:						
Crude	9	3	97	179	106	182
Spinning fibers	266	74	--	--	266	74
All other	20,100	4,110	192	330	20,300	4,440
Crocidolite (blue) 3/	197	37	--	--	197	37
Other (unspecified asbestos type)	817	144	4	2	821	146
Total	21,400	4,370	293	511	21,600	4,880

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ U.S. Customs declared value.
3/ Reported by the Bureau of the Census. Its source and low value suggest the imports labeled as crocidolite were primarily chrysotile.

Source: Bureau of the Census.

TABLE 7
ASBESTOS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina	215	309	319 r/	250 r/	280
Bosnia and Herzegovina e/	500	500	300	--	--
Brazil	170,000	185,000	192,050	170,000 r/	170,000
Bulgaria e/	500 4/	500	500	500	500
Canada	590,641	522,967	531,000	515,587 r/	521,000
China e/	240,000	240,000	303,000 r/	263,000 r/	250,000
Colombia	7,900	--	--	--	--
Egypt	373	436	400 e/	400 e/	400
Greece	30,000 e/	50,000	50,000	75,000 e/	50,000
India	43,683	44,080	29,824 r/	24,984 r/	30,000
Iran e/	4,300	4,500	4,500	4,500	4,500
Japan e/	29,500	24,900	21,000	20,000	20,000
Kazakstan e/	400,000	325,000	300,000	250,000	225,000
Korea, Republic of	2,308	-- r/	-- r/	-- r/	--
Russia e/	1,500,000	1,000,000	800,000	800,000	720,000
Serbia and Montenegro	1,175	314	498	300 e/	300
South Africa	133,268	103,994	92,130	88,642 r/	90,000
Swaziland	32,301	33,860	26,720 r/	28,570 r/	29,000
United States (sold or used by producers)	15,600	13,700	10,100	9,290	9,550 4/
Zimbabwe	150,158	156,881	151,905	169,256 r/	165,000
Total	3,350,000	2,710,000	2,510,000 r/	2,420,000 r/	2,290,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Marketable fiber production. Table includes data available through Apr. 8, 1997.
3/ In addition to the countries listed, Afghanistan, North Korea, Romania, and Slovakia also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.
4/ Reported figure.

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BARITE

By James P. Searls

Barite, a name which was derived from the Greek word "barus," meaning heavy, is the mineralogical name for barium sulfate. In commerce, the mineral is sometimes referred to as "heavy spar" or "barytes." "Spar" means almost any transparent or translucent, readily cleavable, crystalline mineral having a vitreous luster (Thrush, 1968). Few mines in the United States produce a spar grade barite.

As used in this report, the term "primary barite" refers to the first marketable product. This product includes crude barite and the products of simple beneficiation methods, such as washing, jigging, heavy media separation, tabling, flotation, and magnetic separation. Most primary barite requires grinding to a small, uniform size before it is used as a weighting agent in petroleum well drilling mud [American Petroleum Institute (API) or Oil Companies' Materials Association (OCMA) specification barite] or as an addition to industrial products. Barite used for drilling can be blue, black, brown, or gray depending on the ore body; must be finely ground, dense, soft, and chemically inert; must have a specific gravity of 4.2 or greater; must be free of soluble salts; and 90% to 95% of the material must pass through a 325-mesh screen. A small percentage of iron oxide is allowable. In offshore drilling the U.S. Environmental Protection Agency limits the content of mercury to 1 milligram per kilogram of barite, and the content of cadmium to 3 milligrams per kilogram of barite (U.S. Environmental Protection Agency, 1997).

Production

Domestic sales data for barite were derived from a voluntary survey of U.S. operations by the U.S. Geological Survey (USGS). Actual mine production data were not collected because some mines sporadically produce stocks of raw ore, then beneficiate and sell from those stocks for several years. Of the 27 operations to which a survey was sent, 27 reported, representing 100% of the primary barite sold or used by producers. Grinding to API specifications was not usually performed at the mine site because railroad tariffs were higher for finished barite than for crude barite, although some barite was ground at the mine sites in Nevada to supply the Western States, the Western Canadian provinces, and Alaska. Using a verbal, rounded total, the Geological Survey estimated the sales from two grinding plants of imported barite, resulted in data for 29 operations. Of the 27 operations surveyed, 8 were mines, 7 of which had associated beneficiating mills, and 1 mine only sold run-of-mine ore (on a contract basis). In addition, less than 40,000 tons included in the "Quantity" in table 2 was from stocks of a closed mine that was not counted in the "Number of Operations." Mountain Minerals' Elk Creek Mine, was reported by company office staff as depleted and likely to be permanently closed. Baker-Hughes' Miller Mine in Nevada was reported by management as remaining idle. The quantity of primary barite sold or used by producers rose by about 22% from that of 1995 while weighted average prices rose about 16%.

There are 15 barite crushing or grinding operations not geographically associated with mines, which are near the consumers of barite in Illinois, Louisiana, and Texas, and receive imported and some domestic barite for processing. Of those operations, Circle A Construction Inc.'s grinding plant in Elko County, NV, Old Soldier's grinding plant in Abbeville, LA, and Milwhite's grinding plant in Houston, TX, were idled during the year. Excalibar Minerals Inc. opened two grinding plants, one each in Abbeville, LA and Houston, TX, in 1996. The quantity of crushed and ground barite sold rose by about 36% from that of 1995, and the weighted average price rose a modest, approximate 4% from that of 1995.

Consumption

Domestic producers supplied a broad range of barite quality, excluding only the United States Pharmacopoeia barite. Crushing and grinding companies reported only a division of sales between petroleum-well weighting barite and "industrial" barite.

About 94% of the barite sold in the United States was used as a weighting agent in oil- and gas-well drilling fluids, mostly in the Gulf of Mexico region and much smaller amounts used in the Pacific Coast areas. Domestic API barite consumption was driven by oil and gas drilling activity, particularly in those wells that were deeper than about 2,135 meters (7,000 feet) where the petroleum-reservoir pressure increases at a greater rate than hydraulic pressure. Owing to its specific gravity of at least 4.2, barite, which is an environmentally beneficial mineral, is used in slurry form to counterbalance any upwardly vented pretoleum-reservoir pressure. When drilling through fluidized zones, the added weight of the barite slurry creates a hydrostatic pressure that holds back formation pressures and prevents an influx of fluids from the formation into the oil drill hole. Uncounterbalanced petroleum reservoir pressure would allow the crude oil and gas to gush (spray) out of the well. Gushers of crude petroleum were, and still are, extremely dangerous fire hazards, wasteful of crude petroleum, and sources of visual and chemical pollution to the surface area surrounding the well.

Demand for petroleum-well weighting barite (API) rose strongly between 1995 and 1996 owing to deep oil- and gas-

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well drilling off the coasts of Louisiana and Texas and a technological shift within the last 3 years in the well drilling industry that made drilling more efficient and lowered the cost of petroleum wells. This shift led to a resurgence of drilling in the United States and the adjacent Gulf Coast. Additionally, the major international U.S. oil and gas producers and sellers have turned their attention back to the Gulf Coast because of the slow development of the giant international opportunities; other opportunities were also reported onshore (Oil & Gas Journal, 1997b).

Traditionally, the U.S. demand for barite has been explained by the prices of the petroleum products through the numbers of drill rigs used in the United States during the reported year, and this was a partial explanation for 1996. By the yearend, the week-average futures price for light sweet crude oil had risen from $19.17 per barrel at yearend 1995 to $25.85 per barrel (Oil & Gas Journal, 1997c). At midyear 1996, the price for light sweet crude oil was $20.99 per barrel, up more than 9% from yearend 1995 and more than 18% from the midyear 1995 price of $17.74 per barrel (Oil & Gas Journal, 1996a). From midyear 1995 to year end 1996, the week-average futures price for light sweet crude oil increased 46% . The natural gas week-average futures price increased 52% from $2.85 per million British thermal units at the beginning of 1996 to $4.34 per million British thermal units at yearend (Oil & Gas Journal, 1997c), and a 175% increase from midyear 1995. Most of the increase in price occurred in the second half of the year for the midyear price for 1996 was $ 2.61 per million British thermal units (Oil & Gas Journal, 1996b).

The number of gas-directed rigs, as reported by the Baker-Hughes rotary rig count, was 362 rigs in mid-year 1995, 420 at yearend 1995, 465 at midyear 1996, and 496 at yearend 1996 (Oil & Gas Journal, 1997a, 1996a). The Baker-Hughes "Total U.S." rotary rig count at the ends of the years increased by about 14% to 851 rigs at the end of 1996 from 745 rigs at the end of 1995 (Oil & Gas Journal, 1997a).

No subdivisions of industrial enduses of barite are reported because each is less than about 20,000 tons per year. The technical grade end uses are for filler and extender grades, colorants, weighting agents, and feedstock into barium chemicals (Brobst, 1994, p. 131). The construction industry uses marble-sized lumps of barite as a portion of the aggregate in concrete to weight down petroleum pipelines passing through marshes or under rivers. The same sizes will also block radiation in concrete nuclear reactor buildings. The industrial enduses of barite included: barium chemicals for the glass, ceramic products, brick and cement block industries; and barium ferrites and titanates; batteries; brake and clutch pads for automobiles and trucks; gastrointestinal x-rays; paint; rubber; plastics; and photographic print paper. One domestic barite producer has named its white technical grade barite "baryte" to distinguish it from the barite used in petroleum well-drilling. A very small amount was used in research on superconducting materials. Barite used as industrial-grade weighting agents encompass such products as barite in rubber mud flaps for trucks to prevent the flap from being lifted by the air flow around the truck, and in rubber rug backing to keep the rug more stationary.

Prices

Between 1995 and 1996 the USGS revised the nominal average weighted 1995 price of all primary barite sold by U.S. producers to $19.20 per ton. The 1996 nominal average weighted sales price for primary barite was $22.14 per ton in 1996, an increase of 15% from the recalculated 1995 prices. Nominal average prices for the crushed and ground barite rose from $73.03 per ton in 1995 to $75.44 per ton in 1996, an increase of more than 3%. International prices for the middle of the year, as reported in Industrial Minerals, (1996c) were as follows: API, lump, c.i.f. (cost, insurance, and freight) [U.S.] Gulf Coast, Chinese, $51 to $55, Indian, $49 to $52, Moroccan, $49 to $51; unground, OCMA/API, bulk, specific gravity 4.2, f.o.b. (free on board) Morocco, $39 to $41 per ton; ground, bagged, specific gravity 4.22, f.o.b. Morocco, $75 to $80 per ton; ground OCMA/API, big bags (1.5 tons) f.o.b. South Turkey, $60 to $64 per ton; ground OCMA, bulk, delivered Aberdeen [United Kingdom], $69.68 to $80.52 [£45-£52; International Monetary Fund (1996)] per ton, delivered Great Yarmouth [United Kingdom], $80.52 to $92.91 (£52-£60) per ton; micronised, off-white minimum 99% less than 20 micronmeters delivered United Kingdom, $216.78 to $232.27 (£140-£150) per ton, and ground, white paint-grade 96% to 98% $BaSO_4$, 350 mesh, 1 to 5 tons delivered United Kingdom, $301.95 to $340.66 (£195-£220) per ton. The weighted, average c.i.f. price of Chinese exported, lump or crude barite into the U.S. Gulf Coast has risen from $40.83 per ton in 1993 (U.S. Bureau of Mines, 1993) to $52.39 per ton (table 6). China is the world's largest producer and will likely set the lowest delivered price for barite around the world.

World Review

Algeria.—In September, M-I finalized a joint venture agreement with Sonatrach, the state oil company of Algeria (Smith International, Inc., 1997). This joint venture, M-I Algeria S.P.A., will supply an extensive line of drilling, completion and workover fluids as well as advanced production chemicals.

Canada.—In 1994, Mountain Minerals Co. Ltd. entered a joint venture project in China with the Guizhou Provincial Metals and Minerals I/E Corp. (Industrial Minerals, 1996a). The project is a barite grinding plant in the Guizhou Province to supply the Asian market.

Morocco.—In June, M-I Drilling Fluids [owned by Smith International, Inc. (64%) and Halliburton Co. (36%)] bought Anchor Drilling Fluids, A.S. from Transocean A.S. (Norwegian) for US$105 million (Smith International, Inc., 1996). Among its assets, Anchor owned 60% of Compagnie Marocaine des Barytes, which operated the Zelmou barite mine in the Figuig Province and a 60,000-ton-per-year processing plant in Safi. Anchor has experience supplying the North Sea and West African markets.

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Nigeria.—Baroid Drilling Fluids Inc.'s Baroid Nigeria Ltd. entered into a joint venture, called Baroid Drilling Chemical Products Limited, with the Nigerian Barytes Mining and Processing Co. to mine barite in Azara, Plateau State (Industrial Minerals, 1996b). Nigerian Barytes Mining and Processing Co. is a subsidiary of the Nigerian Mining Corp. Baroid owns 60% of the joint venture. The Government of Nigeria has banned the importation of barite to encourage local production to meet the local consumption of about 75,000 tons per year.

Outlook

If the oilfield projects in other countries around the world remain at 1996 levels, then the U.S. market for barite could be healthy for several years. The small market for exported U.S. barite is not likely to change.

It is not clear how long or to what extent the futures price for gas or oil will rise in the next 2 years. If futures oil and gas prices stay above yearend 1993 levels, then the demand for barite should increase. This could allow a price rise in constant dollars and maybe return some idle mines to activity. It is hard, however, to forecast the percentage split of the supply of barite between U.S. mines and imported barite after noting the rising prices for barite imported from China.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT BARITE AND BARIUM CHEMICAL STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Barite, primary:					
Sold or used by producers	326	315 3/	583	543	662
Value	$19,600	$19,300 3/	$19,100	$10,400 r/	$14,700
Exports	12	18	14	16	31
Value	$1,810	$2,610	$1,850	$2,020	$3,190
Imports for consumption 4/	354	804	1,070	1,040	1,540
Value	$17,300	$34,200	$47,200	$52,500	$81,900
Consumption (apparent) 5/	668	1,100	1,640	1,570	2,170
Crushed and ground (sold or used by processors) 6/	999	1,090	1,250	1,370 r/	1,870
Value	$84,400	$79,200	$81,100	$99,800 r/	$141,000
World: Production	4,570 r/	4,250 r/	4,260 r/	4,300 r/	4,460 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Barium chemicals data withheld to avoid disclosing company proprietary data.

3/ Data excludes run of mine.

4/ Includes crude and ground.

5/ Sold or used plus imports minus exports.

6/ Includes imports.

TABLE 2
U.S. PRIMARY BARITE SOLD OR USED BY PRODUCERS, BY STATE 1/

		Total	
State	Number of operations	Quantity (thousand metric tons)	Value (thousands)
1995:			
Nevada	5 2/	479	$7,950
Other States 3/	5 r/	64	2,480 r/
Total	10 r/	543	10,400 r/
1996:			
Nevada	5 2/	W	W
Other States 3/	4	W	W
Total	9	662	14,700

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes one idle mine.

3/ Includes Georgia, Illinois (1995), Missouri, and Tennessee.

TABLE 3
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY STATE 1/ 2/

	1995			1996		
State	Number of plants	Quantity (thousand metric tons)	Value (thousands)	Number of plants	Quantity (thousand metric tons)	Value (thousands)
Louisiana	5	762 r/	$55,300 r/	7	1,090	$80,500
Nevada	4	245 r/	8,800 r/	3	238	10,200
Texas	3 r/	W	W	5	454	33,900
Other 3/	7 r/	359 r/	35,600 r/	6	81	16,100
Total	19 r/	1,370 r/	99,800 r/	21	1,870	141,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes imports.

3/ Includes California, Georgia, Illinois, Missouri, and States indicated by the symbol "W."

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TABLE 4
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	1995 r/		1996	
	Quantity	Value	Quantity	Value
Barium chemicals, filler and/or extender, glass	100	$17,700	102	$16,600
Well drilling	1,270	82,100	1,760	124,000
Total	1,370	99,800	1,870	141,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes imports.

TABLE 5
U.S. EXPORTS OF NATURAL BARIUM SULFATE (BARITE), BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	26	$42	35	$6
Belgium	--	--	24	6
Brazil	4	7	--	--
Canada	14,000	1,140	12,800	1,140
Chile	--	--	1,440	242
Colombia	10	6	33	34
Egypt	--	--	81	35
France	3	6	1	4
Germany	--	--	150	6
Greece	40	9	--	--
Hong Kong	--	--	152	132
Israel	10	56	--	--
Italy	--	--	48	211
Japan	18	293	27	11
Korea, Republic of	--	--	22	15
Mexico	1,430	428	9,660	798
Netherlands	--	--	6	4
Oman	--	--	32	118
Panama	--	--	20	8
Spain	20	5	--	--
Suriname	36	6	--	--
Switzerland	7	12	--	--
Taiwan	19	7	--	--
Thailand	--	--	4	7
United Kingdom	--	--	1	6
Venezuela	--	--	5,960	415
Total	15,600	2,020	30,500	3,190

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF BARITE, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Barite, crude:				
Canada	87	$27	12,700	$2,620
China	699,000	33,900	1,130,000	59,200
India	216,000	7,760	244,000	9,220
Japan	--	--	341	10
Mexico	10,700	474	25,000	1,270
Morocco	38,400	1,890	39,000	1,950
Netherlands	25	15	--	--
Switzerland	--	--	12,100	541
United Kingdom	1	8	--	--
Total	965,000	44,100	1,470,000	74,800
Barite, ground:				
Canada	11,600	2,850	1,500	999
Germany	231	124	55	48
Japan	65	65	--	--
Mexico	66,400	5,360	68,800	5,970
Netherlands	49	25	111	46
United Kingdom	--	--	1	2
Total	78,400	8,430	70,400	7,060

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C.i.f. value.

Source: Bureau of the Census.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF BARIUM CHEMICALS 1/

	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Barium choride	1,110	$651	1,680	$1,260
Barium oxide, hydroxide, and peroxide	4,410	4,890	4,380	4,850
Barium nitrate	3 950	3 450	3,880	2,930
Barium carbonate, precipitated	20,500	13,200	18,900	13,100
Other barium compounds	13,400	13,000	12,400	12,700

1/ Data are rounded to three significant digits.
2/ C.i.f. value.

Source: Bureau of the Census.

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TABLE 8
BARITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Afghanistan e/ 4/	2,000	2,000	2,000	2,000	2,000
Algeria	51,159	47,232	20,590	25,000 e/	25,000
Argentina	10,015	14,761 r/	27,952 r/	27,000 r/ e/	27,000
Australia e/	11,000	11,000	11,000	11,000	11,000
Belgium e/	30,000	30,000	30,000	30,000	30,000
Bolivia	368	-- e/	3,307	10,845	2,000
Bosnia and Herzegovina e/ 5/	3,000	2,000	1,000	1,000	500
Brazil (beneficiated)	54,490	32,068	31,499	30,750 r/	32,000
Burma	13,589	15,628	21,969	34,601	26,000
Canada	37,000	59,000	55,000	61,000 r/	61,000 p/
Chile	2,514	2,035	3,670	3,000 e/	3,000
China e/	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Colombia	9,380	4,840	7,000	21,300	21,000
Croatia e/ 5/	1,500	1,500	1,000	1,000	500
Czechoslovakia 6/ 7/	31,313	XX	XX	XX	XX
Egypt	7,840	1,125	419	500 e/	500
France	96,200 r/	67,200 r/	72,100	75,450 r/	75,000
Georgia e/	40,000	30,000	20,000	20,000	20,000
Germany (marketable)	154,873	147,614	145,223	150,000 e/	150,000
Greece (crude ore) e/	1,000	1,000	1,000	1,000	1,000
Guatemala e/	1,720 8/	1,500	1,000	1,200	1,250
India	458,436	547,875	497,971 r/	420,704 r/	500,000
Iran 4/	181,174	226,378	139,000 e/	150,000 e/	150,000
Ireland	70,600	53,000 e/	-- r/	10,000 r/	10,000
Italy e/	74,884 8/	52,000	60,000	38,000	40,000
Kazakstan e/	300,000 r/	300,000 r/	300,000 r/	286,000 r/	250,000
Kenya	100 e/	14	20 r/	20 r/ e/	20
Korea, Republic of	40	--	85	90 r/	80 8/
Malaysia	10,525	11,551	17,144	16,966	21,000
Mexico	187,730	136,000	86,605	248,367	250,000
Morocco	401,000	325,200	264,526	265,000 e/	265,000
Pakistan	32,432	26,336	20,320	15,360	16,000
Peru	16,579	23,988	53,074	37,420	37,500
Philippines e/	500	500	500	500	500
Poland	14,000 r/	20,400 r/	26,600 r/	22,400 r/	25,000
Portugal e/	378 8/	350	50 r/	50 r/	60
Romania	118,100	115,000 e/	104,700	18,169 r/	12,541 8/
Saudi Arabia	--	2,000	5,000	6,000	8,000 8/
Slovakia e/ 7/	XX	30,000	25,000	25,000	25,000
South Africa	3,570	2,000	1,945	1,990	7,428 8/
Spain	6,194	17,656 r/	28,037 r/	28,600 r/	28,000
Thailand	46,328	42,385	53,248	58,807 r/	59,000
Tunisia	30,179	30,000 e/	10,465 r/	15,200	16,000
Turkey (run-of- mine)	311,335	118,367	116,220	158,000 e/	144,000
United Kingdom	76,723	32,623 r/	54,000	85,000 e/	102,000 8/
United States 9/	326,000	315,000 10/	583,000	543,000	662,000 8/
Zimbabwe	232	120	--	--	--
Total	4,570,000 r/	4,250,000 r/	4,260,000 r/	4,300,000 r/	4,460,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 10, 1997.

3/ In addition to the countries listed, Bulgaria also produces barite, but available information is inadequate to make reliable estimates of output levels.

4/ Data are for fiscal year beginning Mar. 21 of that stated.

5/ Barite concentrates.

6/ Dissolved Dec. 31, 1992.

7/ All production in Czechoslovakia for 1992 came from Slovakia.

8/ Reported figure.

9/ Sold or used by producers.

10/ Data excludes run-of-mine.

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BAUXITE AND ALUMINA

By Patricia A. Plunkert

Bauxite is a naturally occurring, heterogeneous material composed primarily of one or more aluminum hydroxide minerals, plus various mixtures of silica (SiO_2), iron oxide (Fe_2O_3), titania (TiO_2), aluminosilicates (clay, etc.), and other impurities in trace amounts. The principal aluminum hydroxide minerals found in varying proportions within bauxite are: gibbsite, $Al(OH)_3$; and the polymorphs boehmite and diaspore, both AlO(OH).

Bauxites are typically classified according to their intended commercial applications: abrasive, cement, chemical, metallurgical, refractory, etc. Of all bauxite mined, approximately 85% is converted to alumina (Al_2O_3) for the production of aluminum metal, an additional 10% goes to nonmetal uses as various forms of specialty alumina, and the remaining 5% goes to nonmetallurgical bauxite applications. Therefore, the bulk of world bauxite production is currently used as feed for the manufacture of alumina via a wet chemical caustic leach process known as the Bayer process. The majority of the alumina produced from this refining process is smelted to produce aluminum metal by electrolytic reduction in a molten bath of natural or synthetic cryolite ($NaAlF_6$), the Hall-Héroult process.

The nonmetallurgical or specialty applications of bauxite comprise 5% of total worldwide crude ore production. Specifications for these premier grades of bauxite are more stringent than for bauxite used to produce metal and are based on the processing requirements and special properties required of their final commercial products. The natural chemical impurities that exist within these specialty-grade raw materials are not chemically removed from the ore during a refining procedure, as is the case for metallurgical-grade bauxite. Nonmetallurgical ores are utilized in an essentially unrefined chemical form, as direct feed for the production of their ultimate end products. Figures on bauxite production and consumption within nonmetallurgical markets are not commonly available. It is currently accepted, however, that the principal industrial end uses for nonmetallurgical-grade bauxite are in the refractories and abrasives fields, followed by cement applications. In addition, the aluminum chemicals and steel industries also consume significant quantities of bauxite for other applications.

In 1996, 25 countries reported bauxite mine production, and total world production amounted to 114 million metric tons, a 6% increase compared with the production in 1995. Australia, Brazil, Guinea, and Jamaica accounted for about 70% of the total bauxite mined in 1996. The principal sources of nonmetallurgical-grade bauxite are very limited and comprise only a handful of countries: abrasive grade--Australia, China, Guinea, and Guyana; and refractory grade— Brazil, China, and Guyana.

Total known world reserves of bauxite are sufficient to meet cumulative world primary aluminum metal demand well into the 21st century. Although bauxite reserves are unevenly distributed throughout the world, with approximately 90% occurring in about a dozen countries, the sheer magnitude of these reserves (23 billion tons) is sufficient to ensure a readily accessible supply for the future.

U.S. production of alumina (calcined equivalent), derived almost exclusively from imported metallurgical-grade bauxite, increased 4% in 1996 compared with that of 1995. An estimated 88% of the alumina shipped by U.S. refineries went to domestic primary smelters for aluminum metal production. Consumption in various forms by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of the U.S. alumina usage.

World output of alumina increased slightly in 1996. The four principal producing countries, in descending order of quantity of alumina produced, were Australia, the United States, Jamaica, and China. These countries accounted for more than one-half of the world's production.

Legislation and Government Programs

In October 1996, the Defense Logistics Agency (DLA) released its Annual Materials Plan (AMP) for the National Defense Stockpile (NDS) for fiscal year 1997. The new AMP, which went into effect on October 1, 1996, provided for the sale of 915,000 tons (900,000 long tons) of metallurgical-grade bauxite, of which 610,000 tons (600,000 long tons) was Jamaica-type and 305,000 tons (300,000 long tons) was Suriname-type. Additionally, as part of the program, the DLA was authorized to dispose of 81,000 calcined tons (80,000 long calcined tons) of refractory-grade bauxite in fiscal year 1997. These were the maximum amounts recommended for disposal during the fiscal year, and the actual level of sales was dependent upon prevailing market conditions.

During calendar year 1996, the DLA announced the sale of 610,000 tons (600,000 long tons) of Jamaica-type, metallurgical-grade bauxite, of which 305,000 tons was awarded to Reynolds Metals Co. and the remaining 305,000 tons was awarded to Kaiser Aluminum & Chemical Corp. The total sales price was $6.1 million. At yearend, the NDS uncommitted inventory for metallurgical-grade bauxite was 10.5 million tons of Jamaica-type and 4.98 million tons of Suriname-type. The NDS calcined refractory-grade bauxite inventory was 153,000 tons.

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Production

Bauxite.—C-E Minerals acquired the mineral reserves of Harbison-Walker Refractories Division at Eufala, AL. C-E reported that by buying these reserves, it has ensured that the company will have strategic reserves to last well into the next millennium. Harbison-Walker announced that it was discontinuing the production of its Ucal range of high-alumina clays to concentrate on manufacturing and selling lightweight refractory aggregates (Skillen, 1996).

Alumina.—The Aluminum Co. of America (Alcoa) reported that a 365,000-ton-per-year (t/yr) expansion at its Point Comfort, TX, refinery had been completed, increasing annual capacity to 2.3 million tons. Approximately 20% of the refinery's output supplies industrial chemicals operations at that location (Aluminum Company of America, 1997). *(See table 2.)*

The oversupply of alumina and the drop in market prices were factors in Reynolds' decision to temporarily curtail 250,000 t/yr of production at its Sherwin refinery near Corpus Christi, TX. Alcoa also announced that its was temporarily curtailing production by 350,000 t/yr. However, Alcoa's production cutback was to be spread over the company's refinery system worldwide (Metal Bulletin, 1996e). *(See table 3.)*

C-E Minerals purchased the Baton Rouge, LA, calcined and tabular alumina plant of LaRoche Industries Inc. However, LaRoche will continue to own and operate its activated alumina manufacturing facilities also located at this site (Industrial Minerals, 1996a).

Consumption

Total domestic consumption of bauxite was at the same level as that of 1995. Approximately 95% of the bauxite consumed in the United States in 1996 was refined to alumina, and an estimated 2.2 tons of dried bauxite was required to produce 1 ton of alumina. Domestic production and consumption data for bauxite and alumina were obtained by the U.S. Geological Survey from three separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Bauxite Consumption" survey, sent to 50 operations, 35 of which responded, representing 89% of the total bauxite consumed shown in table 4.

An estimated 88% of the alumina shipped by U.S. alumina plants went to domestic primary smelters for aluminum metal production. Twenty-one primary aluminum smelters reported a consumption of 7.12 million tons of alumina in 1996. Consumption in various forms by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of U.S. alumina usage.

Prices

Most metallurgical-grade bauxite and alumina are purchased under long-term contracts. Contract terms for these commodities normally are not made public. However, spot prices for metallurgical-grade alumina and specialty forms of bauxite and alumina for nonmetallurgical applications are published in trade journals.

Industrial Minerals magazine quoted prices at the end of the year for several types of imported refractory-grade bauxite from China and Guyana. The price quotes for Chinese refractory-grade bauxite, minimum 87% Al_2O_3, f.o.b. Chinese ports were as follows: Shanxi, shaft, lump, $70 to $80 per ton; Shanxi, rotary, lump, $95 to $105 per ton; and Guizhou, round, lump, $78 to $85 per ton. The price ranges for Guyanese refractory-grade bauxite were $155 to $165 per ton f.o.b. barge, U.S. Gulf Coast and $165 to $175 per ton c.i.f. Europe. *(See table 8.)*

The market or spot prices for alumina decreased substantially during most of the year. According to *Metal Bulletin*, metallurgical-grade alumina spot prices on international markets began the year at $220 to $250 per ton. The price range reached a low for the year of $145 to $150 per ton in late July. The price remained at this level through mid-November before rising slightly to $150 to $160 per ton, and held steady at this level through the end of the year. Trade data released by the U.S. Bureau of the Census indicated the average value of U.S. imports of calcined alumina was $221 per ton, f.a.s. port of shipment, and $234 per ton, c.i.f. U.S. ports.

Foreign Trade

In addition to the trade data shown in tables 9, 10, and 11, various specialty aluminum compounds were also exported from and imported into the United States. Specialty aluminum compounds exported included 2,840 tons of aluminum sulfate, 8,090 tons of aluminum chloride, 11,900 tons of aluminum oxide abrasives, and 20,900 tons of various fluoride-base compounds of aluminum, including synthetic cryolite and aluminum fluoride. Specialty aluminum compounds imported included 40,400 tons of aluminum sulfate, 2,690 tons of aluminum chloride, 131,000 tons of aluminum oxide abrasives, and 18,300 tons of various fluoride-base aluminum compounds.

World Review

World production of bauxite and alumina increased slightly in 1996 in response to a slight increase in metal production. Twenty-five countries reported mine production in 1996, and total world production amounted to about 114 million tons, 6% higher than that in 1995. Australia, Guinea, Jamaica, and Brazil, in decreasing order of tonnage mined, continued to be the largest producers of bauxite and accounted for about 70% of total world production. *(See table 12.)*

World output of alumina increased about 1% in 1996 compared with that of 1995. The four principal producing countries, in order of quantity of alumina produced, were Australia, the United States, Jamaica, and China. These countries accounted for more than one-half of the world's production. *(See table 13.)*

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Australia.—Alcan Aluminium Ltd. commissioned its Australian subsidiary, Alcan South Pacific Pty. Ltd., to generate a detailed feasibility study and environmental impact statement on the development of its Cape York Peninsula bauxite reserves in Northern Queensland. The site contains approximately 175 million tons of proven bauxite reserves. The studies should be completed by early 1997 and, if viability is confirmed, mining could commence in late 1999. The ore from this mine would replace third-party purchases and would be dedicated to Alcan's alumina production requirements at nearby Queensland Alumina Ltd. (21.4% ownership) and at Aughinish Alumina Ltd. (100% ownership) in Ireland (Alcan Aluminium Ltd., 1996).

Comalco Ltd. announced a major overhaul of its Weipa bauxite operations to improve its competitive position, enhance the long-term security of the mine, and facilitate Comalco's proposed alumina refinery investment. The plan includes reduction and renewal of the mine's truck fleet, extension of the mine railway network, and upgrading of the bauxite beneficiating plant (Comalco Ltd., 1996).

Worsley Alumina Pty. Ltd. announced a 150,000-t/yr expansion at its 1.7-million-t/yr refinery near Collie in Western Australia. The expansion was expected to be completed by late 1997. The company also has begun a feasibility study to assess a subsequent and much larger expansion program that would increase capacity to 3.5 million t/yr (Mining Magazine, 1996).

Azerbaijan.—Responsibility for the management of the 400,000-t/yr Gyandzha alumina refinery reportedly was transferred to Azeral, a subsidiary of Trans-World Metals, a London-based trading and industrial holding group. The refinery has been at a virtual standstill for some time, and Trans-World estimates that a minimum initial investment of about $45 million would be required to carry out essential repairs and to provide working capital for the plant. When working at capacity, Trans-World forecasts that about 300,000 t/yr of alumina could be produced from imported bauxite, while the remaining 100,000 t/yr would be produced from locally available alunite. The plant would also produce about 80,000 t/yr of high-grade potassium sulfate as fertilizer for local use and 200,000 t/yr of sulfuric acid (Metal Bulletin, 1996f).

Brazil.—Mineração Rio do Norte S.A. (MRN) announced that bauxite production at its mines reached a record 9.6 million tons. MRN also reported that the domestic market consumed about 5 million tons of this bauxite, a 39% increase compared with consumption in 1995 (Mineração Rio do Norte S.A., 1997).

Companhia Vale do Rio Doce (CVRD) reported that production at its Alunorte alumina refinery reached 826,000 tons, almost 80% of the refinery's nominal capacity, during its second year of operation. With the addition of alumina production at Alunorte, CVRD has become a fully integrated primary aluminum producer (Companhia Vale do Rio Doce, 1997).

Alcoa Aluminio S.A. operates the Alumar Consortium (Alumar), a joint venture that owns a large refining and smelting project near São Luis. In late 1996, the Alumar refinery was expanded by 260,000 t/yr, bringing total annual capacity to 1.3 million tons (Aluminum Company of America, 1997).

Canada.—In July, severe flooding in the Saguenay-Lac-Saint-Jean region of Quebec destroyed a water pumping station that supplied the 1.2-million-t/yr Vaudreuil alumina complex. Operations were temporarily disrupted, resulting in the loss of approximately 70,000 tons of alumina production (Alcan Aluminium Ltd., 1997).

China.—Prejon International BV, a Netherlands-based mineral distributor, entered into a joint venture with Guizhou Xianghai Industry Trading Co. to develop a bauxite deposit in southwestern Guizhou Province. The deposit reportedly has estimated bauxite reserves of 200 million tons. The companies expect the new mine to produce 100,000 t/yr of bauxite (Industrial Minerals, 1996b).

Alcoa World Alumina & Chemicals reportedly signed an agreement with China National Nonferrous Metals Industry Corp. (CNNC) to supply 400,000 t/yr of alumina to CNNC's aluminum smelter system for the next 30 years (Regan, 1996).

Guinea.—According to the Ministry of Mines and Geology, Guinea is seeking to increase its bauxite production. In addition to improvements at existing mines to bring production back to planned capacity levels, two new projects are under consideration. Dian-Dian, one of Guinea's richest deposits, reportedly has reserves of more than 500 million tons of bauxite grading 45% to 52% alumina. The $1.9 billion project is designed to produce about 11 million tons of bauxite per year, of which 7.5 million tons would be exported. The second project is the Dabola project that would initially produce about 600,000 t/yr of bauxite for export to Iran. A $2 million feasibility study is also under way for the construction of a 1.2-million-t/yr alumina plant at Dabola (Metal Bulletin, 1996a).

Hungary.—Hungalu Magyar Aluminiumpari Rt reported progress in its efforts to privatize the country's aluminum industry. Two of Hungalu's three alumina refineries have been sold, and the third, Ajka Aluminium, has been offered for sale. Magyaróvár Alumina and Alundum Ltd.'s alumina refinery, a producer of nonmetallurgical alumina products, was sold to Altus-GPS, a Hungarian consortium. The Aloxid Almásfüzitö refinery was sold to Hungalumina, a consortium consisting of Alucan (50%), Alfer (25%) and Metalservice (25%), (Metal Bulletin, 1996b).

India.—India's Cabinet Committee on Economic Affairs reportedly approved National Aluminium Co. Ltd.'s proposal for expansion of its bauxite mines and alumina refinery. The project involves the doubling of bauxite mine capacity from 2.4 million t/yr to 4.8 million t/yr and increasing alumina refinery capacity from 800,000 t/yr to almost 1.6 million t/yr (Metal Bulletin, 1996c).

Kazakstan.—An investment agreement reportedly has been signed with TransWorld Group to finance the construction of a new aluminum smelter and the expansion of alumina production capacity. The Pavlodar refinery was expected to have its capacity increased from 1.1 million t/yr to 2 million t/yr (Platt's Metals Week, 1996).

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Romania.—Balli Trading of the United Kingdom acquired a 51% interest in the Alum alumina refinery and developed a production program to increase output at the plant, currently 250,000 t/yr, to 370,000 t/yr in 1997 and to 600,000 t/yr in the near future (Metal Bulletin, 1996d).

Ukraine.—The Industry Ministry announced plans to close the 245,000-t/yr Zaporozhye alumina plant because of high energy requirements and the need for extensive reconstruction and modernization. The alumina requirements of the adjacent smelter would be supplied by Ukraine's other alumina refinery, the 1.1-million-t/yr Nikolayev refinery (American Metal Market, 1996).

Vietnam.—The Prime Minister reportedly has approved a prefeasibility study for the construction of an aluminum complex in the Province of Lam Dong. The proposed refinery and smelter would produce between 150,000 and 200,000 t/yr of alumina and 75,000 t/yr of metal. The facility would be supplied with bauxite from a local mine with estimated reserves of 300 million tons (Mining Journal, 1996).

Outlook

Presently identified world bauxite reserves are sufficient to meet cumulative world demand well into the next century. Considering the high probability of discovering additional bauxite deposits, plus the added possibility of employing lower grade bauxite occurrences and various alternative sources of alumina, world resources of aluminum remain adequate to satisfy demand for the foreseeable future.

The quality and quantity of bauxite resources within the former Eastern bloc nations are incapable of sustaining an economically viable market-based aluminum industry. Therefore, significant amounts of imported bauxite and alumina will be required to supply their primary aluminum production facilities. In addition, China recently has become a fairly significant buyer of alumina on the spot market. The rapid expansion of its primary aluminum industry has led to periodic shortages of feed material, and China has turned to the spot market to fill these needs.

During the first half of 1997, production of alumina appears to have increased slightly. The temporary production cutbacks announced by Alcoa and Reynolds during the latter part of 1996 have begun to come back on-stream. In the long term, worldwide demand for aluminum is expected to grow steadily, thereby increasing the demand for bauxite and alumina feedstocks.

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TABLE 1
SALIENT BAUXITE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Production: Crude ore (dry equivalent)	W	W	W	W	W
Value	W	W	W	W	W
Exports (as shipped)					
Crude and dried	54	85	114	86	92
Calcined	9	5	15	22	40
Imports for consumption (as shipped)					
Crude and dried	10,900	11,600	10,700	10,100	10,200
Calcined	346	238	349	482	352
Consumption (dry equivalent)	11,900	12,200	11,200	10,900	10,900
World: Production	105,000	109,000 r/	104,000 r/	107,000 r/	114,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.

TABLE 2
PRODUCTION AND SHIPMENTS OF ALUMINA IN THE UNITED STATES 1/

(Thousand metric tons)

			Total	
Year	Calcined alumina	Other alumina 2/	As produced or shipped 3/	Calcined equivalent
Production: e/				
1995	4,030	730	4,760	4,530
1996	4,150	807	4,960	4,700
Shipments: e/				
1995	4,120	740	4,860	4,630
1996	4,140	806	4,950	4,700

e/ Estimated.
1/ Data are rounded to three significant digits.
2/ Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.
3/ Includes only the end product if one type of alumina was produced and used to make another type of alumina.

TABLE 3
CAPACITIES OF DOMESTIC ALUMINA PLANTS, 1/ 2/ DECEMBER 31

(Thousand metric tons per year)

Company and plant	1995	1996
Aluminum Co. of America:		
Point Comfort, TX	1,740	2,300
St. Croix, VI 3/	600	600
Total	2,340	2,900
Kaiser Aluminum & Chemical Corp.: Gramercy, LA	1,000	1,050
Ormet Corp.: Burnside, LA	600	600
Reynolds Metals Co.: Corpus Christi, TX	1,600	1,600
Total	5,540	6,150

1/ Capacity may vary depending on the bauxite used.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Purchased from Virgin Islands Alumina Co. in 1995.

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TABLE 4
U.S. CONSUMPTION OF BAUXITE, BY INDUSTRY 1/

(Thousand metric tons, dry equivalent)

Industry	1995	1996
Alumina	10,100	10,300
Abrasive	133	118
Chemical	201	21
Refractory	394	386
Other	55	55
Total	10,900	10,900

1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 5
PRODUCTION AND SHIPMENTS OF SELECTED ALUMINUM SALTS IN THE UNITED STATES IN 1995 1/

Item	Number of producing plants	Production (thousand metric tons)	Total shipments, including interplant transfers: Quantity (thousand metric tons)	Total shipments, including interplant transfers: Value (thousands)
Aluminum sulfate:				
Commercial and municipal (17% Al2O3)	66	1,040	999	$109,000
Iron-free (17% Al2O3)	17	155	161	17,300
Aluminum chloride:				
Liquid and crystal	7	28	W	W
Anhydrous (100% AlCl3)	3	28	28	19,800
Aluminum fluoride, technical	3	W	W	W
Aluminum hydroxide, trihydrate [100% Al(OH)3]	11	960	1,000	227,000
Aluminates	15	183	182	38,200
Other aluminum compounds 2/	XX	XX	XX	189,000

W Withheld to avoid disclosing company proprietary data. XX Not applicable.
1/ Data are rounded to three significant digits.
2/ Includes light aluminum hydroxide, cryolite, etc.

Source: Data are based on Bureau of the Census 1994 Current Industrial Reports, Series MA-28A, "Inorganic Chemicals."

TABLE 6
STOCKS OF BAUXITE IN THE UNITED STATES, 1/ 2/ DECEMBER 31

(Thousand metric tons, dry equivalent)

Sector	1995	1996
Producers, processors, and consumers	1,730	2,060
Government	16,300	15,700
Total	18,100	17,800

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Domestic and foreign bauxite; crude, dried, calcined, activated, all grades.

TABLE 7
STOCKS OF ALUMINA IN THE UNITED STATES, 1/ 2/ DECEMBER 31

(Thousand metric tons, calcined equivalent)

Sector	1995	1996
Producers	325	326
Primary aluminum plants	1,100	1,020
Total	1,420	1,350

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes consumers stocks other than those at primary aluminum plants.

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TABLE 8
AVERAGE VALUE OF U.S. IMPORTS OF CRUDE AND DRIED BAUXITE 1/

(Per metric ton)

Country	1995		1996	
	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
Australia	$10.60	$20.05	$19.64	$31.54
Brazil	23.31	31.93	29.83	39.28
Guinea	22.45	28.89	26.57	33.60
Guyana	25.00	38.93	25.19	37.09
Jamaica	25.02	30.50	25.83	31.34
Weighted average	23.51	30.64	26.89	34.24

1/ Computed from quantity and value data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF BAUXITE, CRUDE AND DRIED, 1/ BY COUNTRY

(Thousand metric tons)

Country	1995	1996
Imports: 2/		
Australia	134	84
Brazil	1,720	2,080
Guinea	3,890	3,420
Guyana	793	693
Indonesia	23	--
Jamaica 3/	3,550	3,920
Other	7	36
Total	10,100	10,200
Exports:		
Canada	82	70
Mexico	1	1
Other	2	22
Total	86	92

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes bauxite imported to the U.S. Virgin Islands from foreign countries.
3/ Dry equivalent of shipments to the United States.

NOTE.--Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands) as reported by the Bureau of the Census were as follows: 1995--10,000,000 tons and 1996--9,930,000 tons.

Sources: Bureau of the Census and the Jamaica Bauxite Institute.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF CALCINED BAUXITE, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995				1996			
	Refractory grade		Other grade		Refractory grade		Other grade	
	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Imports:								
Australia	--	--	15	1,140	--	--	(3/)	28
Brazil	3	284	38	3,210	6	654	6	553
China	131	5,940	154	8,770	119	7,410	118	8,890
Guyana	71	9,460	--	--	59	8,110	26	633
Other	17	1,370	54	1,830	17	1,730	1	72
Total	223	17,000	259	14,900	201	17,900	151	10,200
Exports:								
Canada	1	227	1	102	(3/)	84	8	657
Japan	13	2,650	--	--	22	5,240	--	--
Mexico	2	284	2	221	3	371	1	188
Other	1	134	1	241	3	871	1	413
Total	18	3,300	4	564	29	6,570	11	1,260

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Value at foreign port of shipment as reported to U.S. Customs Service.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF ALUMINA, BY COUNTRY 1/

(Thousand metric tons, calcined equivalent, and thousand dollars)

Country	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Imports:				
Australia	2,910	552,000	3,120	590,000
Brazil	24	8,970	6	5,410
Canada	80	50,500	102	63,800
France	9	12,400	11	14,800
Germany	35	66,000	42	76,100
India	147	29,800	68	27,100
Jamaica	270	61,000	351	68,100
Japan	10	20,200	7	15,400
Suriname	305	49,200	379	76,500
Trinidad	116	23,300	147	27,900
Venezuela	18	8,110	35	21,900
Other	73	26,500	58	34,600
Total	4,000	908,000	4,330	1,020,000
Exports:				
Brazil	28	9,500	2	3,370
Canada	744	185,000	712	187,000
Finland	(3/)	634	(3/)	439
Mexico	39	20,900	44	36,900
Netherlands	13	14,400	21	19,000
Norway	(3/)	124	(3/)	162
Russia	138	24,200	75	15,100
Sweden	(3/)	141	(3/)	486
Other	81	98,600	64	111,000
Total	1,040	353,000	918	374,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Value at foreign port of shipment as reported to U.S. Customs Service.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 12
BAUXITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Albania e/	4	2	2	1	1
Australia	39,746	41,320	41,733	42,655	43,100 3/
Bosnia and Herzegovina e/	200 3/	100	75	75	75
Brazil	9,366	9,669	8,673	9,700 r/	9,700
China e/	2,700	3,500	3,700	5,000	6,200
Croatia	7	2	1 e/	-- r/	--
Ghana	338	424	426	530 r/	473
Greece	2,078	2,205	2,196	2,006 r/	2,168 3/
Guinea e/ 4/	13,800	14,100	11,300 r/	12,000 r/	14,000
Guyana e/ 4/	2,376 3/	2,126 3/	2,100	2,100	2,000 3/
Hungary	1,721	1,561	900 r/	840 r/	1,044 3/
India	4,898	5,277	4,809	5,163 r/	5,100
Indonesia	804	1,320	1,342	899	1,000
Iran e/	100	100	100	100	100
Italy e/	98 3/	90	23 r/	11 r/	--
Jamaica 4/ 5/	11,302	11,391	11,564	10,857	11,829 3/
Kazakstan	3,036	3,000 e/	2,425	3,071 r/	3,140
Malaysia	331	269	162	184	219 3/
Mozambique	8	6 e/	10	11 e/	9
Pakistan	3	5	5	3 r/	4 3/
Romania	175	186	184	174	175 3/
Russia	4,578	4,260	3,000 e/	3,100 e/	3,300
Serbia and Montenegro	792	102	--	60 r/	320
Sierra Leone	1,250 e/	1,165	735	-- r/	-- 3/
Suriname	3,250	3,412	3,772	3,530 r/	4,000
Turkey 6/	613	538	445	232 r/	200
United States	W	W	W	W	W
Venezuela	1,052	2,910 e/	4,419	5,184	5,600 p/
Total	105,000	109,000	104,000 r/	107,000 r/	114,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data through June 25, 1997.

3/ Reported figure.

4/ Dry bauxite equivalent of crude ore.

5/ Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

6/ Public-sector production only.

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TABLE 13
ALUMINA: WORLD PRODUCTION, 1/ BY COUNTRY 2/ 3/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Australia	11,783	12,598	12,892	13,147	13,318 4/
Azerbaijan e/	300	200	100	27 4/	5
Bosnia and Herzegovina e/	100	50	50	50	50
Brazil	1,833	1,853	1,868	1,883 r/	1,870
Canada	1,104	1,180	1,170	1,064	1,000
China e/	1,580	1,820	1,850	2,200	2,490
Czechoslovakia e/ 5/ 6/	143	XX	XX	XX	XX
France	508	476	438	519 r/	500
Germany	857	840	824	825 e/	850
Greece	612	615	584	598 r/	601 4/
Guinea	561	656	640 r/	566 r/	600
Hungary	548	421	177	184 r/	208 4/
India	1,484 r/	1,490 r/	1,456 r/	1,650 r/	1,700
Ireland	973	1,103 r/	1,786 r/	1,186 r/	1,234 4/
Italy 7/	762	840 e/	852 r/	857 r/	850
Jamaica	2,917	2,989	3,221	3,030	3,200 4/
Japan 8/	316	327	322	320 e/	300
Kazakstan e/	1,100	1,000	900	1,022 r/ 4/	1,083 4/
Romania	280	293	302	323	259 4/
Russia	2,718 r/	2,500 e/	2,254	2,300 r/ e/	2,105 4/
Serbia and Montenegro	197	12	--	54 r/	50
Slovakia e/ 6/	XX	140	75	100	100
Slovenia e/	45	40	40	40	40
Spain 7/	959	1,060 e/	1,071 r/	1,095 r/	1,000
Suriname	1,576	1,507 r/	1,497 r/	1,589 r/	1,600
Turkey	156	169	155	173 r/	155
Ukraine e/	1,100	1,010	1,070	1,100	1,000
United Kingdom e/	120	105	105	108 r/	100
United States	5,190	5,290	4,860	4,530	4,700 4/
Venezuela	1,308	1,500	1,300 e/	1,641	1,700
Total	41,100 r/	42,100 r/	41,900 r/	42,200 r/	42,700

e/ Estimated. r/ Revised. XX Not applicable.

1 /Figures represent calcined alumina or the total of calcined alumina plus the calcined equivalent of hydrate when available; exceptions, if known, are noted.

2/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

3/ Table includes data available through July 25, 1997.

4/ Reported figure.

5/ Dissolved Dec. 31, 1992.

6/ All production in Czechoslovakia for 1992 came from Slovakia.

7/ Hydrate.

8/ Data presented are for alumina used principally for specialty applications. Gross weight of aluminum hydrate for all uses was as follows, in thousand metric tons: 1992--714; 1993--704; and 1994-96--not available.

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BERYLLIUM

By Deborah A. Kramer

Beryllium, a material valued for its light weight and stiffness, is used in a wide number of applications where these properties are important. In 1996, production of beryllium ore increased from the 1995 level, and total consumption of end products—beryllium alloys, beryllium metal, and beryllium oxide—also increased. *(See table 1.)* The introduction of new beryllium-aluminum alloys is opening new markets, in both the defense and commercial sectors, for beryllium products.

Legislation and Government Programs

On March 14, Brush Wellman Inc. filed a petition with the U.S. International Trade Commission alleging that the U.S. beryllium industry was threatened with material injury by imports of beryllium metal and high-beryllium alloys from Kazakstan. The imports covered under this investigation were beryllium metal in ingot, billet, powder or block form, which is traded under the Harmonized Tariff Schedule of the United States (HTS) subheadings 8112.11.30 and 8112.11.60, and beryllium alloys containing greater than 30% beryllium by weight, particularly aluminum-beryllium alloys covered under HTS 7601.20.90 (U.S. International Trade Commission, 1996). On August 28, the International Trade Administration made a preliminary determination that beryllium metal and high-beryllium alloys from Kazakstan would be subject to a dumping margin of 70.80% for the period of investigation of July 1, 1995, through December 31, 1995 (U.S. Department of Commerce, International Trade Administration, 1996). The final determination was scheduled for January 1997. The United States imported 23 metric tons of beryllium metal from Kazakstan in 1995.

In its Annual Materials Plan for fiscal year 1997, the Defense Logistics Agency (DLA) is authorized to dispose of a maximum of 1,800 metric tons of beryl ore. (This is the same quantity as was allowable in the 1995 and 1996 Annual Materials Plans, none of which has been sold.) On December 20, 1996, the Defense National Stockpile Center—DLA awarded the entire 1,800 tons to Muelege International for $400,000 (Defense National Stockpile Center, 1996). *(See table 2.)*

The Department of Energy (DOE) planned to hold two forums in January 1997 to collect scientific data and information to aid in developing occupational beryllium exposure standards for DOE employees and contractors. DOE was concerned that workers who were exposed to beryllium prior to 1989 were at risk for chronic beryllium disease, and the agency was concerned with potential exposure for workers participating in decontamination and decommissioning work in some of DOE's nuclear facilities in the future. Information gathered in the forums was expected be used in proposed rulemaking (U.S. Department of Energy, 1996).

Production

The United States is one of only three countries that can process beryllium ore and concentrates into beryllium products and supplies most of the rest of the world with these products. Brush Wellman mines bertrandite and converts this ore, along with beryl, into beryllium hydroxide at its facility in Delta, UT. Beryllium hydroxide is shipped to the company's plant in Elmore, OH, where it is converted into beryllium alloys, oxide, and metal.

One other company in the United States has the capability to produce beryllium alloys. NGK Metals Corp., a subsidiary of NGK Insulators of Japan, produces beryllium alloys at a plant near Reading, PA. Because NGK Metals does not have facilities to process the raw materials, the company purchases beryllium oxide from Brush Wellman.

Brush Wellman announced plans to begin an expansion at its Elmore, OH, facility with new capacity to be operational by 1998. Additional equipment for melting, casting, rolling, and finishing beryllium-copper strip will constitute the bulk of the company's $110 million program. In conjunction with the capacity increase, the new equipment was expected to reduce production costs, reduce delivery times, and reduce work-in-process inventory requirements. No specific measure of increased capacity was announced (Metal Bulletin, 1996).

Beryllium data are collected from two voluntary surveys of U.S. operations. In 1996, there were four responses to the "Beryllium Mineral Concentrate and Beryllium Ore" survey, representing 100% of the total canvassed. These respondents produced 100% of total domestic mine shipments, shown in tables 1 and 7. A small number of unidentified producers may have shipped insignificant quantities of byproduct beryl, which have not been included.

Environment

Beryllium dust and fumes have been recognized as the cause of beryllosis, a serious chronic lung disease. In the 1940's, the disease was diagnosed among industry employees and their relatives, who had handled dusty workclothes prior to the establishment of suitable hygienic procedures. Cases also were reported among residents of communities surrounding beryllium-processing plants. Although uncertainties related to the cause of the disease still exist, the problem appears to be controlled when established preventative measures are exercised. In beryllium-processing plants, harmful effects are prevented by maintaining clean workplaces; requiring the use of

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safety equipment such as personal respirators; collection of dust, fumes, and mists at the source of deposition in dust collectors; medical programs; and other procedures to provide safe working conditions. Control of potential health hazards adds significantly to the final cost of beryllium products.

Consumption

According to its annual report, Brush Wellman reported that its worldwide sales in 1996 were $376.3 million, with international sales of $74.8 million. This was a 2% increase in sales from the 1995 level. Increases in sales of beryllium alloys more than offset declines in sales of beryllium metal and beryllium oxide ceramic material. Shipments of beryllium-copper alloys to the automotive electronics and telecommunications markets increased, and at the same time, beryllium oxide ceramic shipments to these same markets declined (Brush Wellman Inc, 1996).

Nuclear Metals Inc. (NMI) was awarded a trademark for its Beralcast® beryllium-aluminum alloy in 1996, which was expected to lead to new uses for the metal in investment castings in aerospace applications. Three military systems—the Army's RAH-66 Comanche helicopter, the Air Force's F-22 fighter plane, and the Army's PAC-3 missile system—already use Beralcast® investment castings. Beralcast® is 25% lighter and almost three times greater in stiffness than aluminum, which makes it suitable for aerospace and satellite applications.

NMI received several contracts for its Beralcast® components during 1996. The company received a $2.4 million add-on contract for prototype components for the Comanche helicopter from Lockheed Martin Inc., which required NMI to build an additional 23 prototype components over and 18-month period. This would bring the total number of NMI-produced prototypes to 36 (Nuclear Metals Inc., 1996c). NMI also was awarded a contract by Honeywell Satellite Systems for its Miniature Inertial Measurement Unit system. This guidance system will be used in some commercial satellites and represents the first use of Beralcast® investment castings for this type of application (Nuclear Metals Inc., 1996a). Lockheed Martin, through its subsidiary Sanders, awarded NMI a contract for Beralcast® components for use in its Advanced Threat Infrared CounterMeasures (ATIRCM) program. The ATIRCM program is the U.S. Department of Defense's next generation missile warning system, and systems are being designed for numerous Army, Navy, and Air Force aircraft. NMI anticipated that 200 systems per year will be constructed over the next 10 to 20 years, which have a sales potential of $20 million (Nuclear Metals Inc. 1996b).

Beryllium-Copper Alloys.—Beryllium-copper alloys are used in a wide variety of applications and average about 75% of annual U.S. consumption on a beryllium metal equivalent basis. These alloys, most of which contain approximately 2% beryllium, are used because of their high electrical and thermal conductivity, high strength and hardness, good corrosion and fatigue resistance, and nonmagnetic properties. Beryllium-copper strip is manufactured into springs, connectors, and switches for use in applications in automobiles, aerospace, radar and telecommunications, factory automation, computers, home appliances, and instrumentation and control systems. The principal use of large-diameter beryllium-copper tubing is in oil and gas drilling equipment and in bushings and bearings in aircraft landing gear and heavy machinery. Connectors in fiber-optic telecommunications systems are the main application for beryllium-copper rod. Small, pluggable sockets for joining integrated circuits to printed circuit boards are the main application for beryllium-copper wire. Beryllium-copper bar and plate are used in resistance-welding parts, components for machinery and materials-handling systems, and for molds to make metal, glass, and plastic components.

Beryllium also is used in small quantities in nickel- and aluminum-base alloys. Miniature electronic connector components that operate at high temperatures are the main use for beryllium-nickel alloys, and these alloys are used in automotive passive restraint systems (air bags). Beryllium-aluminum alloys are used as castings in the aerospace industry. Addition of small quantities of beryllium to magnesium alloys inhibits oxidation.

Beryllium Metal.—Beryllium metal, which averages about 10% of annual U.S. beryllium demand, is used principally in aerospace and defense applications. Its high stiffness, light weight, and dimensional stability over a wide temperature range make it useful in satellite and space vehicle structures, inertial guidance systems, military aircraft brakes, and space optical system components. Because beryllium is transparent to X-rays, it is used in X-ray windows. In nuclear reactors, beryllium also serves as a canning material, as a neutron moderator, in control rods, and as a reflector. In the past, the metal had been used as a triggering device in nuclear warheads. Other applications for metallic beryllium include high-speed computer components, audio components, and mirrors. In the U.S. space shuttles, several structural parts and brake components use beryllium.

Beryllium Oxide.—Beryllium oxide (beryllia) is an excellent heat conductor, with high hardness and strength. This material also acts as an electrical insulator in some applications. Beryllium oxide, averaging about 15% of domestic beryllium demand, serves mainly as a substrate for high-density electronic circuits for high-speed computers, automotive ignition systems, lasers, and radar electronic countermeasure systems. Because it is transparent to microwaves, microwave communications systems and microwave ovens may use beryllium oxide.

Because of its high cost compared to those of other materials, beryllium is used in applications in which its properties are crucial. Steel, titanium, or graphite composites substitute for beryllium metal in some applications, and phosphor bronze substitutes for beryllium-copper alloys, but these substitutions result in substantial loss in performance. In some cases, aluminum nitride may be substituted for beryllium oxide.

Prices

Quoted prices for beryllium metal increased significantly from those at yearend 1995. The beryllium powder price

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increased by 31%, and vacuum-cast beryllium ingot price increased by 6%. Published beryllium oxide price increased by 9%. *(See table 3.)*

Foreign Trade

The Bureau of the Census does not separately identify all imports and exports of beryllium-copper alloys. The Journal of Commerce Port Import/Export Reporting Service (PIERS) provides some data on materials that are transported by ship. According to PIERS, 1,190 tons (gross weight) of beryllium-copper alloys in strip and billet form were imported in 1996, primarily from Japan. Exports of beryllium-copper alloys totaled 57 tons (gross weight), with Japan (44%) and Hong Kong (26%) as the principal recipients. *(See tables 4 and 5.)*

World Review

In Canada, interest was renewed in the Thor Lake beryllium property in the Northwest Territories. In May, Mountain Minerals Co. Ltd. purchased Conwest Exploration Co. Ltd.'s 34.7% interest in Highwood Resources Ltd., the largest owner of the Thor Lake property (North American Mineral News, 1996). In August, Mountain Minerals announced a plan to merge with Highwood Resources and planned to begin additional work on the Thor Lake property after the merger is complete. The company planned to conduct a feasibility study on the property to determine the economics of producing either beryllium oxide or beryllium metal (Platt's Metals Week, 1996). The project has been idle since 1990 when work on a pilot plant was halted because of insufficient sales commitments. Reserves at the property were estimated at 479,000 tons of ore grading 1.4% BeO and 1.3 million tons of ore, grading 0.66% BeO. *(See tables 6 and 7.)*

Outlook

Beryllium alloys are expected to remain the dominant form of consumption for beryllium. Consumption of alloys should continue to increase in the United States, particularly with the introduction of beryllium-aluminum alloys. Although applications using the new alloys are not as high-volume as traditional beryllium-copper alloy applications, each application contains more beryllium per use (greater than 60% vs. 0.5% to 2% for beryllium-copper).

The United States should be able to continue to supply its beryllium requirements with domestically mined ore. According to its annual report, Brush Wellman reports proven bertrandite reserves of 6.135 million tons at yearend 1996, with an average grade of 0.249% beryllium (Brush Wellman Inc., 1996). At an average annual U.S. consumption of 250 tons of beryllium, proven bertrandite reserves would last more than 60 years.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium metal equivalent unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Beryllium-containing ores:					
Mine shipments	193	198	173	202	211
Imports for consumption, beryl 1/	2	2	--	--	1
Consumption, reported	196	196	174	227	234
Yearend stocks	111	114	113	162	139
World: Production 1/	278	270	246 r/	274 r/	281 e/

e/ Estimated. r/ Revised.

1/ Based on a beryllium metal equivalent of 4% in beryl.

TABLE 2
STOCKPILE STATUS, DECEMBER 31, 1996

(Metric tons, beryllium content)

Material	Goal	Uncommitted inventory	Authorized for disposal
Beryllium-copper master alloy	287	268	--
Beryllium metal	363	363	--
Beryllium ore	653	545	545

TABLE 3
YEAREND BERYLLIUM PRICES

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore	per short ton unit of contained BeO	$78- $85
Beryllium vacuum-cast ingot, 98.5% pure, in lots up to 1,000 pounds		327
Beryllium metal powder, in 1,000- to 4,999-pound lots and 98.5% pure		385
Beryllium-copper master alloy	per pound of contained Be	160
Beryllium-copper casting alloy		5.52- 6.30
Beryllium-copper in rod, bar, wire		9.85
Beryllium-copper in strip		8.90
Beryllium-aluminum alloy, in 500-pound lots; 62% Be, 38% Al		260
Beryllium oxide powder, in 10,000-pound lots		77.00

Sources: American Metal Market, Brush Wellman Inc., and Platt's Metals Week.

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TABLE 4
U.S. EXPORTS OF BERYLLIUM ALLOYS, WROUGHT OR UNWROUGHT, AND WASTE AND SCRAP, 1/ BY COUNTRY 2/

Country	1995 Quantity (kilograms)	1995 Value (thousands)	1996 Quantity (kilograms)	1996 Value (thousands)
Canada	6,640	$255	25,200	$683
France	10,700	2,270	3,530	749
Germany	16,500	338	5,490	792
Japan	19,000	1,620	4,380	905
Netherlands	341	104	5,760	247
Norway	--	--	5,970	51
United Kingdom	7,070	696	1,170	317
Other	1,000 r/	512 r/	5,220	762
Total	61,300	5,800	56,700	4,510

r/ Revised.
1/ Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.
2/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM ORE, METAL, AND COMPOUNDS 1/

Material	1995 Quantity (kilograms)	1995 Value (thousands)	1996 Quantity (kilograms)	1996 Value (thousands)
Beryl ore	--	--	19,400	$9
Beryllium-copper master alloy	94,200	$880	31,300	549
Beryllium oxide and hydroxide	8,310	112	9,090	58
Beryllium, unwrought and waste and scrap	32,200	2,830	19,100	1,920

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY, 1/
DECEMBER 31, 1996

(Metric tons, contained beryllium)

Continent and country	Capacity
North America: United States 2/	360
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa	3
Zimbabwe	5
Total	19
Asia: China	75
Europe:	
Kazakstan	7
Portugal	3
Russia	70
Total	80
South America:	
Argentina	4
Brazil	65
Total	69
Grand total	603

1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Includes bertrandite ore.

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TABLE 7
BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996
Argentina	34	35 4/	--	--	--
Brazil	850	850	900 r/	900 r/	850
Kazakstan	100	100	100	100	100
Madagascar 5/	3	3	3	3	3
Namibia	10	15 4/	15	15	--
Portugal	4	4	4	4	4
Russia	1,100	800	800	800	800
United States 6/ (mine shipments)	4,830 4/	4,940 4/	4,330 4/	5,040 4/	5,260 4/
Zambia	1	1	1	1	1
Zimbabwe (concentrate, gross weight)	23	(7/)	(7/)	(7/)	(7/)
Total	6,950	6,750	6,150 r/	6,860 r/	7,020

r/ Revised.

1/ World totals, U.S. data and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 8, 1997.

3/ In addition to the countries listed, China produced beryl and Bolivia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production.

4/ Reported figure.

5/ Includes ornamental and industrial products.

6/ Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

7/ Less than 1/2 unit.

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BISMUTH

By Robert D. Brown, Jr.

One domestic refinery in Nebraska produced bismuth as a byproduct of lead refining; however, most of the bismuth consumed in the United States was imported. Thirty-six companies, mostly in the Eastern United States, accounted for an estimated 80% of the bismuth consumed in 1996. About 56% of bismuth production was used in pharmaceuticals and chemicals, 27% in bismuth alloys, 15% as metallurgical additives, and 2% in other uses. After the anomalously high consumption of 1995, domestic demand fell nearly 30% in 1996, returning to a level more typical of recent years. Only a small amount of bismuth is obtained by recycling old scrap.

Several newly developed uses for bismuth providing nontoxic substitutes for lead have been introduced in recent years. These include the use of bismuth in fishing sinkers, brass plumbing fixtures, pigments, ceramic glazes, solders, lubricating greases, and crystalware. However, the only application showing a consistent, significant increase in demand through the lead replacement scenario is bismuth shot for waterfowl hunting.

In recent years, world production has remained steady. Sales from the National Defense Stockpile (NDS) also remained steady. Domestic production declined for 1996, as net imports rose. The New York dealer price for bismuth averaged $3.65 per pound for 1996. This was the first decrease after 2 years of significant increases. The value of bismuth consumed domestically was more than $12 million.

Bismuth is the leading candidate for replacing lead in applications that have an environmental impact. The U.S. Fish and Wildlife Service granted final approval for the use of bismuth shot for waterfowl hunting. The Safe Drinking Water Act Amendments of 1996 will eventually ban the use of lead in plumbing materials that contact drinking water.

The largest foreign producers (in decreasing order) of refined bismuth were Mexico, Peru, Belgium, and China.

Legislation and Government Programs

The Defense Logistics Agency (DLA), which administers the NDS sold 122 metric tons of bismuth from the stockpile in 1996: 84 tons in September and 38 tons in November (American Metal Market, 1996a, b). The September sale, combined with 52.5 tons sold on November 15, 1995, represented slightly more than the 136 tons allocated for disposal in fiscal year 1996, which ended September 30, 1996. The DLA was authorized to dispose of another 136 tons of bismuth in fiscal year 1997. The NDS inventory on December 31, 1996, was 191.5 tons.

The U.S. Fish and Wildlife Service granted final approval of the use of 97% bismuth-3% tin shot for waterfowl hunting. This approval was granted on the basis of further testing by the Bismuth Cartridge Council, which found that the shot was not toxic when ingested by waterfowl. The bismuth-tin shot is the leading alternative to steel shot, which replaced lead for waterfowl hunting several years ago (Fish and Wildlife Service, 1997).

The U. S. Congress passed, and the President signed, the Safe Drinking Water Act Amendments of 1996, (Public Law 104-182) which will eventually require all pipes, fixtures, solders, and fluxes used for the installation or repair of facilities providing water for human consumption to be lead-free.

Production

ASARCO Incorporated was the only domestic producer of primary bismuth. Production for 1996 decreased compared to that for 1995. To avoid disclosing company proprietary information, production data were not published. Some firms recovered bismuth from fusible alloy scrap, but secondary production data were not available. It is estimated that secondary production accounts for 5% or less of the domestic supply.

On April 15, 1996, many months after such a resolution had been foreseen by industry watchers, Asarco announced that it had reached agreement with the City of Omaha, NE, to cease all operations at its Omaha refinery by February 1, 1998, and to remediate the property for use as a park. It would have cost the company $40 million in improvements to meet current and pending environmental standards. The company stopped lead refining at Omaha on June 1, 1996, but planned to continue processing other materials, including bismuth, at the plant until June 1997 (ASARCO Incorporated, 1997). By this step, the result of long discussions on emission controls, modernization, and cost-benefit analysis, the United States will lose its only domestic source of primary bismuth. Consumers' fears about supply seemed to have peaked before the announcement was made, and the long lead time before actual shutdown of the bismuth operations appeared to have softened such concerns.

Consumption

Domestic consumption data are collected through a voluntary survey. Of the 45 firms that received the consumption survey form in 1996, 73% responded. The respondents accounted for an estimated 80% of the bismuth consumption in the United States. The amount used by the nonrespondents was estimated on the basis of reports from prior years or information from other sources.

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Compared to the record- setting year of 1995, 1996 brought a significant decrease in domestic consumption. By weight, chemicals had the largest demand increase in 1995 and the largest decrease in 1996. Bismuth alloys had the largest percentage increase in 1995 and the second largest decrease in 1996.

As in several recent years, chemical uses accounted for more than one-half of the bismuth used domestically. The best known chemical use is that of bismuth subsalicylate, the active ingredient in over-the-counter stomach remedies. Other bismuth pharmaceuticals are used to treat burns, stomach ulcers, intestinal disorders, and for veterinary applications. Other bismuth chemical and compound uses include widely varying applications, ranging from pearlescent pigments in cosmetics and paints to superconductors.

The metallic uses of bismuth are categorized in table 2 into bismuth alloys, metallurgical additives, and other uses. Fusible (low-melting-point) alloys are combinations of bismuth and other metals such as cadmium, gallium, indium, lead, and tin. Applications for these alloys include holding lenses or other parts for machining or grinding, solders, fire sprinkler triggering mechanisms, and fuel tank safety plugs. Also included in bismuth alloys is the metal used to produce shot for waterfowl hunting.

Bismuth is added in relatively small percentage amounts to aluminum, copper, and steel alloys to improve machinability. It is also added to malleable iron to prevent the formation of graphite flakes.

Interest remained high in using bismuth as a nontoxic substitute for lead in several applications. Bismuth oxide replaces lead oxide in the fire assaying of precious metals. Bismuth replaces lead in ceramic glazes, and bismuth shotgun pellets are replacing the steel ones that replaced lead. Bismuth is the primary candidate for substitution when researchers seek to remove lead from products that traditionally have contained lead, such as plumbing fixtures and solders. Research and development continues on the use of bismuth (often in combination with selenium) to replace lead in plumbing brasses. Although this strategy appears to be the most promising metallurgical approach to meeting forthcoming more stringent tap water standards in the United States, bismuth consumption for this application has not yet increased significantly.

Since 1994, one area of large, steady increases has been the use of bismuth alloy cartridges for waterfowl hunting. The alloy used is 97% bismuth and 3% tin.

Prices

The domestic dealer price for commercially pure bismuth, published by Platt's Metals Week, averaged about $3.65 per pound for the year, representing a 5% ($0.20) decrease after increases of 30% ($0.75) and 18% ($0.60) in 1994 and 1995, respectively. The price was $4.20 per pound at the beginning of 1996, having gradually increased from a low of $3.55 per pound in July, 1995. The price declined gradually throughout 1996 to a low of $3.15 per pound in early December and then increased to $3.30 per pound in mid-December, where it held steady until the end of the year.

Foreign Trade

Total imports increased 3% by weight and 11% by value in 1995, even though imports from Belgium, the largest supplier, decreased. A small increase from Mexico and larger increases from the United Kingdom and China offset the decrease from Belgium. Of nine supplying countries, the four largest--Belgium, Mexico, the United Kingdom, and China--in descending order, accounted for 92% of the total.

Exports fell 42% by weight and 44% by value in 1996. Exports remained small (about 10% by weight and 17% by value) compared to imports.

World Review

China, Mexico, and Peru, had abundant bismuth to supply the world market at low prices (Mining Journal, 1966a, b). This apparent indicator of adequate supply kept prices down for the year in spite of the expected shutdown of the only U.S. bismuth-producing plant.

Usually, bismuth is recovered as a byproduct of lead or tungsten production. The Tasna Mine in Bolivia, which was closed in 1985, is the world's only significant potential source where bismuth would be the principal product. The new owners, Corriente Resources, Inc. of Vancouver, continued to obtain promising results from studies of the feasibility of reopening the mine. Corriente adjusted the mine's established reserves from 400,000 to 500,000 tons graded at 1.47% bismuth and 1.28% copper, with credits for gold, silver, and tungsten. Additionally, a new vein was discovered in a previously unworked area of the property with grades of 3% bismuth, 1.43% copper, 0.2% tungsten, and 4.21 grams of gold per ton. Other veins have been discovered, with less bismuth but higher gold content. The company purchased a nearby smelter that must be converted from zinc to bismuth-copper production, but the acquisition will eliminate costly exportation of concentrates for smelting. The company expects the mine to produce 900 to 1,000 tons of bismuth and 10,000 to 15,000 ounces of gold annually, but has projected the need for a steady price of $4.00 per pound of bismuth to start up.

Current Research and Technology

The most common soldering alloy for electronic applications, tin with 37% lead, has a melting point of 183° C and requires board temperatures of 205° C to 220° C to enable the alloy to form acceptable soldered joints. A newly developed replacement alloy of tin plus 42% lead and 8% bismuth allows a 10° C drop in processing temperature. The further addition of 0.5% silver allows another 5° C drop in temperature and provides higher strength and ductility in the soldered joint than in the original tin-lead alloy. This is a case where the properties of bismuth make the manufacturing process more efficient even

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though lead is still present in the alloy (McCormack, and others, 1996).

Researchers from many academic and industrial laboratories followed various approaches to obtain lead-free solders for electronics applications. Studies included the tin-bismuth, tin-zinc-bismuth, tin-silver-bismuth, tin-bismuth-indium, and tin-bismuth-antimony systems. The research done by industrial laboratories included potential applications in communications and transportation (Journal of Metals, 1996).

Outlook

The long-range outlook for bismuth indicates that demand should increase, especially as development activity continues in the area of nontoxic replacements for lead. Demand has increased fairly slowly in recent years, with a big increase in 1995. Because bismuth is most often a byproduct of lead, a rapid increase in supply is unlikely, especially because the total consumption of lead remains fairly flat, with a large fraction of lead demand satisfied by recycling. Some relief would be provided by the resumption of production at the Tasna Mine in Bolivia, the world's only mine where the principal product would be bismuth. Furthermore, changes at Cominco's Trail, British Columbia, smelter to make its bismuth recovery process "continuous" rather than "campaign" should increase production.

Significant increases in demand for new applications, except for shot for waterfowl hunting, still appear to be a few years away. In summary, the big changes in supply and demand are not occurring as rapidly as earlier anticipated. This has stabilized the bismuth market for the near future.

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TABLE 1
SALIENT BISMUTH STATISTICS 1/

(Metric tons)

	1992	1993	1994	1995	1996
United States:					
Consumption	1,300	1,300	1,490 r/	2,150	1,520
Exports 2/	90	70	160	261	151
Imports for consumption	1,620	1,330	1,660	1,450	1,490
Price, average, domestic dealer, per pound	$2.66	$2.50	$3.25	$3.85	$3.65
Stocks, Dec. 31: Consumer	272	323	402	390	122
World:					
Mine production (metal content) 3/	2,870 r/	3,220 r/	3,060 r/	3,490 r/	3,440 e/
Refinery production 3/	3,710 r/	4,360 r/	4,070 r/	4,260 r/	4,230 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Comprises bismuth metal and the bismuth content of alloys and waste and scrap.

3/ Excludes the United States.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Chemicals 2/	1,320	855
Bismuth alloys	544	401
Metallurgical additives	257	231
Other	27	35
Total	2,150	1,520

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

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TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY 1/

Country	1995 Quantity (kilograms, metal content)	1995 Value (thousands)	1996 Quantity (kilograms, metal content)	1996 Value (thousands)
Argentina	--	--	137	$11
Australia	--	--	197	5
Belgium	157,000	$1,200	65,500	220
Brazil	32	4	50	6
Canada	43,200	1,880	59,500	1,410
Chile	54	3	--	--
China	30,300	39	--	--
Dominican Republic	112	4	1,150	35
Finland	--	--	472	4
France	15,500	137	5,380	77
Germany	--	--	497	38
Guatemala	--	--	14,200	16
Hong Kong	80	4	--	--
Ireland	414	12	227	9
Korea, Republic of	--	--	63	18
Mexico	363	13	51	4
Netherlands	307	8	209	7
Norway	58	5	--	--
Saudi Arabia	1,480	7	--	--
Singapore	2,320	23	144	8
Switzerland	--	--	2,220	20
Taiwan	650	9	--	--
Thailand	--	--	45	4
United Kingdom	9,680	83	596	44
Total	261,000	3,430	151,000	1,930

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value (thousands)	1996 Quantity (kilograms)	1996 Value (thousands)
Belgium	636,000	$4,850	584,000	$4,690
Bolivia	28,300	146	--	--
Canada	83,900	367	80,800	675
China	82,600	605	151,000	1,180
Germany	1,360	189	498	104
Hong Kong	21,500	174	15,800	128
Japan	1,350	30	1,680	90
Korea, Republic of	10,000	75	--	--
Mexico	444,000	3,220	453,000	3,380
Peru	10,900	94	19,500	164
United Kingdom	131,000	663	189,000	1,090
Other	265	9	--	--
Total	1,450,000	10,400	1,490,000	11,500

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 5
BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	Mine					Refinery				
	1992	1993	1994	1995	1996 e/	1992	1993	1994	1995	1996 e/
Belgium e/	--	--	--	--	--	800	950	900	800	800
Bolivia	--	--	--	121 r/	125	30 r/	7 r/	36	19 r/	20
Bulgaria e/	40	40	40	40	40	40	40	40	40	40
Canada 3/	224	144	129	187 r/	185	--	--	--	--	--
China e/	820	740	610 r/	740 r/	700	1,060	1,050	850 r/	800 r/	800
Italy	--	--	-- e/	-- e/	--	20	--	5 e/	5 e/	5
Japan 4/	159 e/	149 e/	152 e/	177 e/	169	530	497	505	591	563 5/
Kazakstan e/	160 r/	160 r/	160 r/	155 r/	155	170 r/ 5/	170 r/	170 r/	166 r/ 5/	160
Korea, Republic of 4/	9 e/	5 e/	-- e/	-- e/	--	9	5	-- e/	-- e/	--
Mexico 6/	807	908	900 e/	995 r/	1,000	550 e/	650 e/	650 e/	924 r/	925
Peru	550 e/	1,000 e/	1,000 e/	1,000 e/	1,000	419	937	871	870 e/	870
Romania e/	50	40	40	40	40	50	35	35	35	35
Russia e/	5	4	4	4	4	10	9	9	10	10
Serbia and Montenegro	10	5	5 e/	5 e/	5	20	10	(7/)	(7/)	(7/)
Tajikistan e/	20	16	12	11	5	--	--	--	--	--
United Kingdom e/	--	--	--	--	--	-- r/	--	--	--	--
United States	W	W	W	W	W	W	W	W	W	W
Uzbekistan e/	15	10	10	10	11	--	--	--	--	--
Total	2,870 r/	3,220 r/	3,060 r/	3,490 r/	3,440	3,710 r/	4,360 r/	4,070 r/	4,260 r/	4,230

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 20, 1997. Bismuth is produced primarily as a byproduct of other metals, mostly lead; Bolivia is the sole producer of primary bismuth.

3/ Figures listed under mine output are the metal content of concentrates produced.

4/ Mine output figures have been estimated based on reported metal output figures.

5/ Reported figure.

6/ Refined metal includes Bi content of imported smelter products.

7/ Less than 500 kilograms. Production in kilograms: 1994--88; 1995--86; and 1996--100 (estimated).

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BORON

By Phyllis A. Lyday

Boron is produced domestically only in the State of California. Boron products sold on the market are produced from a surface mine, underground mines, in situ, and from brine. The United States and Turkey are the world's largest producers of boron, changing positions from year to year. Boron is priced and sold on the boron oxide basis, which varies by ore and compound and on the absence or presence of sodium and calcium. Boron exports are about one-half of the domestic production.

Legislation and Government Programs

The Department of Energy began disposing of radioactive waste using a vitrification process that used boron and lithium at its Savannah River Site. The site, operated by Westinghouse Savannah River Co., is the home of the world's largest waste vitrification technology center. The 132,490 cubic meters (35 million gallons) of radioactive waste now in storage will be concentrated to drive off the water and then separated from the solid salts by chemical reactions. The results will be 1,890 cubic meters (500,000 gallons) of radioactive waste. The time to vitrify the current amount of waste was estimated at 20 years. The waste is mixed with a premelted molten glass containing boron and lithium that is poured into a canister for cooling and storage. About 1% of the waste mixture is radioactive. The Savannah River site will be used as an interim facility until the year 2020. In the future, the canisters will be moved to a repository 1.6 kilometers (1 mile) deep under ground. The only other vitrification site in operation is in West Valley, NY. The Richland, WA, site plans to begin operations between the year 2000 and 2005. The Idaho Falls, ID, plant is 20 years from being operational (Lafferty, 1996).

Members of International Code Council, a nonprofit organization jointly staffed and funded by the United States' three national model code organizations, expect the new International Building Code (IBC) to be operational by the year 2000. Boron products are used in products that cover fire resistance, insulation, roofing, glass, and other home construction products. The IBC will utilize the three existing codes—the Building Officials and Code Administrators International, Inc., BOCA National Building Code (BNBC); Uniform Building Code (UBC) from the International Conference of Building Officials (ICBO); and the Standard Building Code from Southern Building Code Congress International, Inc. (SBCCI)—as a basis for defining the model. Besides the three existing codes, nine Southern States have separate State codes. The IBC will make it simpler and more cost effective for building professionals to comply with U.S. code requirements and will present a set of uniform codes and standards for builders and suppliers based outside the United States. These firms want to advertise nationally, but want to have their products recognized and usable under a single set of standards. U.S. architects, engineers, builders, subcontractors, and building suppliers are spending more time and money complying with multiple and sometimes conflicting codes. The approach has been to use the best of what is being utilized and apply the code nationally (Engineering News Record, 1996).

Production

Domestic data for boron were developed by the U.S. Geological Survey from a voluntary survey of U.S. operations. The majority of boron production continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA. Of the four operations to which a "sold and used" survey request was sent, four responded, representing 100% of the total boron sold or used. *(See table 1.)*

American Borate Co. mined small amounts of colemanite and ulexite/probertite from the Billie Mine. Colemanite was processed at Lathrop Well, NV. Storage and grinding facilities were at Dunn, CA. *(See table 2.)*

Fort Cady Minerals Corp. produced a salable product named CADYCAL 100. The product was 43% boron oxide that screens 81% less than 325 mesh. Because CADYCAL is a chemically precipitated product, it has advantages in consistency of the chemical compositionl; i.e., high boron oxide content, low impurities, and consistent physical size. The design of a larger facility was initiated with Flour-Daniel, Inc., which was awarded the design contract. Production of 30,000 tons per year with expansion to 90,000 tons per year was planned.

North American Chemical Co. (NACC), owned by the Harris Chemical North America, Inc., is headquartered in New York and has operating headquarters in Overland Park, KS. NACC operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. Searles Lake is a dry lake playa with three major subsurface evaporite horizons. NACC owns 3,964 hectares (9,197 acres). NACC implemented technical changes in its production operation that took effect April 1996. A 243-hectare (600 acre) area was selected that contains the highest concentration of borax reserves in the lake, about 8,000 tons per 0.40 hectares (1 acre) or reserves of 4.8 million tons. A series of closed systems will circulate brines in the upper unit salt layer of the lake to increase the borax grade to a theoretical 1.45%. The brine will be processed at the Westend plant and circulated through a heat

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exchanger back to the upper salt layer. The Trona Railway operated between Trona and Searles Station and connected to the Southern Pacific Railroad. The boron products transported were used in ceramics, high-temperature glassware, and insulation.

NACC announced the completion of the sale and leaseback of its Argus electric- and steam-generating facility in Searles Valley, CA, on July 25. Steam and electricity from the Argus Utilities facility serve NACC's production facilities at its Searles Valley complex. Net proceeds from the sale were $70 million which were used to reduce debt under its existing revolving credit agreement. Under terms of the agreement, NACC will lease back the Argus facility for a term of 15 years, including a 2-year bargain renewal period. The lease provides for three renewal periods of up to 5 years each through the life of the facility.

U.S. Borax, Inc. (Borax) is a wholly owned subsidiary of RTZ-CRA. On December 21, 1995, The RTZ Corp. PLC and CRA Ltd. merged to form The RTZ Corp. PLC, CRA Ltd, and Group Companies (RTZ-CRA). Group companies are separate and independently managed. RTZ-CRA planned an annual investment of $40 million during the next 5 years at its Boron, CA, mine and refinery. The deposit contains reserves up to 113 million tons of sodium borates and an addition 198 million tons of calcium borates. (Review, 1996). There are sufficient reserves to last 40 years at current mining rates. Borax currently extracts bout 18 million tons per year of material, including 2.7 million tons of ore averaging 23% boron oxide content (Mining Journal, 1996). The deposit is a sequence of borax and kernite crystals interbedded with claystone. The world-class sodium borate deposit at Boron was being developed by modern open pit operations. Using a German-made Orenstein & Koppel RH120c, the hydraulic shovel digs from the top down. This reduces the level of loaded bucket hoisting and keeps the ore horizons separate (Borax Pioneer, 1996a). Calcium borate ore is stockpiled.

Tincal ore is dissolved in hot borate solutions. Clear borax solution is cooled to precipitate a decahydrate and pentahydrate borax. After drying, the products are stored bulk or bagged and palletized.

Kernite ore is dissolved in a mixture of sulfuric acid and hot borax liquor. The solution is filtered and pumped to tanks that feed the crystallizes where boric acid is formed. The boric acid crystals are washed and dried. Production is stored in bins for sampling and then transferred to storage silos for shipment. A 25% increase in boric acid capacity was announced by the company to bring capacity to 200,000 tons per year (Glass, 1996a).

During 1995, a new system to dewater and wash pentahydrate borax and boric acid was installed at Boron, CA. The system uses vacuum belt filters and a series of three washes to provide a product with greater consistency and already reduced levels of sulfate, carbonate, chloride, and arsenic. The use of the gentler process reduced crystal damage and reduced the dust fraction from 12% to 5% for boric acid and from 6% to less than 2% for the pentahydrate borax.

Variations in heat caused by the installation of a new dryer resulted in the product being too dry, causing fines, or too moist, both of which contribute to caking. The startup problems were corrected in September, and the improved products are available to customers all over the world. (Borax Pioneer, 1996b).

Boron operates a zero discharge operation. Waste water is impounded and evaporated to recover borate material. More than 360,000 tons of borate has been recovered in the past decade.

The majority of material from Boron was shipped to Borax's storage in Wilmington, CA, part of the Port of Los Angeles. Products made at Wilmington are used in agricultural, industrial, and speciality applications. U.S. mined products are loaded onto bulk carriers for transport to terminals at Rotterdam, the Netherlands, and Valencia, Spain, that provide for the unloading, inspection, packing, and distribution of European orders. At the Borax refining complex at Coudekerque, near Dunkirk, France, pharmaceutical, technical, and special quantity grades of borax and boric acid are manufactured for the European market. Recently, Borax expanded its distribution network by establishing warehouse facilities in Russia and the Ukraine.

During the year, Borax formed a separate speciality chemicals department to focus on borate flame retardants. Demand for the fire retardants is growing 15% per year. Speciality chemicals accounted for about 11% to 12% of Borax's sales. Borax has more than doubled its zinc borate fire-retardants plant capacity in Wilmington during a $3 million expansion. Zinc borate is used with, or in place of, antimony trioxide, serving as a promoter in chlorine- or bromine-based fire-retardant systems. Zinc borate has an advantage over other materials because it forms a glassy char that inhibits combustion and suppresses smoke. It is also less expensive than antimony trioxide. Patented and sold under the trade name Firebrake 415, the new zinc borate can tolerate temperatures up to 415° C. This allows for its use in nylon, which is processed at 300° C. Firebreak 500, another zinc borate, can withstand temperatures well over 1,000° C (Chemical Engineering, 1996).

Consumption

Glass accounts for three major borate applications, as follows: glass fiber insulation, borosilicate glass, and textile glass fiber. The use of borates in glass fiber thermal insulation, primarily used in new construction, was a large area of demand for borates and the principal insulating material used in the construction industry. Composed of very thin fibers spun from molten glass, its purpose is to trap and hold air. Typically between 4% and 5% boron oxide is incorporated in the formulation to aid melting, inhibit devitrification, and improve the aqueous durability of the finished product.

Borates also were used in manufacturing high-tensile-strength glass fiber materials used in a range of products. The process of producing glass fiber uses a borosilicate E-glass formulation that is continuously drawn through platinum alloy

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bushings into continuous filaments of between 9 and 20 microns in diameter. E-glass, or textile fiberglass, typically contains between 6% and 8% boron oxide. Originally these glasses were used for electrical purposes, and low sodium levels were important. Major applications were reinforcements for plastics, but the low sodium tolerance still applies to the requirements for the production of the reinforced glass. The nonconductive and low dielectric properties of high-strength glass-reinforced materials make them transparent to radar and thus valuable for "stealth" applications. E-glass, a calcium aluminoborosilicate glass that has a balance of mechanical, chemical, and electrical properties, is widely applied in composites because of the moderate cost.

Boron, added in amounts of between 10% and 13% to glass, reduced the viscosity of the melt, assisted with fiber formation during processing, allowed for improved specific optical properties, increased resistance to aqueous or chemical attack, enhanced certain mechanical properties, and reduced the thermal expansion coefficient and thermal shock resistance.

Boron is important to many speciality glasses such as heat-resistant domestic Pyrex glass and optical glass. Boron imparts a low thermal expansion level. The most common forms of boron minerals are borax (tincal), ulexite, colemanite, and kernite. In glass such as Pyrex, sodium borates or boric acid is commonly used. In optical glass, boric acid is commonly used (Industrial Minerals, 1996a).

PPG Industries Inc. is increasing the production of fiberglass chopped strand for reinforcing polyethylene terephalate (PET) polyester to meet growing demand in automotive composite applications. The company is also expanding production of a chopped strand fiberglass reinforcement for nylon resin in auto applications (Glass Industry, 1996b).

Fiberglass insulation represents the largest secondary market for recycled glass containers in the United States. A recent survey reported that more than 425 million kilograms (936 million pounds) of recycled glass was used in the manufacture of fiberglass insulation in 1995. This resulted in a savings of 708,000 cubic meters (25 million cubic feet) of landfill space. Estimated figures for 1996 are calculated at more than 454,000 tons (1 billion pounds). According to officials of North American Insulation Manufacturers Association, the industry average is about 30% recycled glass, but some manufacturing facilities are averaging up to 40%, depending on availability of the recycled glass (Glass Industry, 1997).

Boron compounds continued to find application in the manufacture of biological growth control chemicals for use in water treatments, algicide, fertilizers, herbicides, and insecticides. Boron was applied as a spray and incorporated in herbicides, fertilizers, and irrigation water. Boron is a micronutrient essential to crop growth.

Boron compounds were used as flame retardants where they reduced flammability by melting and preventing oxygen from contact with the burning surface. Although not as effective as other flame retardants, they were less expensive. In cellulose materials such as timber, particle board, paper, wood fiber, and cotton products, sodium borates and boric acid were used. Anhydrous borax was used in the manufacture of flame-retardant fiberboard. In plastics, zinc borate was the most widely used borate compound.

The alloys of the nonmetal boron and neodymium and iron metals produced the strongest magnetic material known. The permanent magnets are used in automotive direct-current motors, computer disk drives, portable power tools, and home appliances.

Boron also was used as a bleaching agent in detergents and cleaning products, such as concentrated washing powders. Perborates carry active oxygen that form hydrogen peroxide in solution. Perborate tetrahydrate was displaced by perborate monohydrate, which was more soluble in cool laundry wash water temperatures.

Prices

The price for boron compounds increased except for high-purity anhydrous boric acid, which decreased more than 27%. Reported prices increased between 3% and 18%.(*See table 3.*) Prices of colemanite imported from Argentina averaged $364 per ton during 1996.

An Industrial Mienrals Prices & Data 1996 was published that included information on Turkish, British, Argentinian, and United States prices of boron minerals and compounds (Industrial Minerals Information Ltd., 1997).

Foreign Trade

The General Agreement on Tariffs & Trade (GATT) that was signed into law in December 1994 and took effect January 1, 1995. GATT lowered chemical tariffs by an average of 30%. Chemicals, including bromine, are the Nation's largest export commodities, as more than 10 cents out of every export dollar is a product of the chemical industry. The agreement's intellectual property provisions include greater patent protection for products developed by U.S. firms. GATT changes patent enforcement from 17 years from the date of issue to 20 years from the date of application. Patents issued on applications filed before June 8, 1995, will be enforceable for either 17 years from the issue date or 20 years from the filing date, whichever is longer.

The majority of material from the Borax facility in Boron was shipped to storage, loading, and shipping facilities at Wilmington, CA. A large part of the output was exported to Western Europe from Wilmington to Botlek, Netherlands. A distribution center and bulk borate terminal was located at Rotterdam, Netherlands; a boric acid plant at Coudekerque, France; warehouses in Valencia, Spain, and Widnes, UK.; and laboratories at Guildford, United Kingdom. *(See tables 4 and 5.)*

World Review

Argentina.—The Republic recently enacted an environmental supplement to its federal mining code, known as

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law No. 24,585. The enforcement of its terms will fall to mining authorities. Under the Argentine Constitution, legislative power is primarily lodged in the Provinces, with the central government having only those powers delegated to it. All the Provinces have ratified the mining code. Regulated activities covered by the act fall into two broad categories. The initial category includes all operations from prospecting through mining development, extraction, and closure. The second group includes all postextraction treatment, including mining recovery, grinding, milling, smelting, refining, and waste disposal (Trower, 1996).

Borax Argentina S.A. was the country's leading producer of borates. Borax mines tincal at Tincalayu, hydroboracite at Sijes, and ulexite from two dry lake beds, Salar Cauchari and Salar Quisquiro, all in the Salta Province at elevations more than 4,000 meters (14,000 feet). The tincal and ulexite are processed at Quijano, near Salta. Most of the production is shipped to South American customers through Campo Quijano.

Ulex S.A. produces colemanite and hydroboracite in Salta Province. At the Sol de Manana Mine, colemanite and hydroborocite were mined. Ulexite, found in veins, is hand mined for resale to two boric acid producers.

Boron deficiency was a major problem with sunflowers in Argentina, the world's leading exporter of sunflower oil. Farmers in the temperate plain do not need artificial fertilizers because the soil is rich in nitrogen and phosphorus. Boron fertilization applied to the leaves produced an average yield increase of 20%. Economic analysis showed that a 20% increase in sunflower production gives a 35% increase in net income. The use of boron fertilizers on Argentinian sunflowers can increase the return on capital by 56% (Borax Pioneer, 1996c).

Bolivia.—Boron Chemical International and Teck Corp., both Vancouver-based companies, were exploring and evaluating a number of ulexite deposits. One feasibility study was completed on a deposit close to the Chilean border. A 75,000-ton-per-year operation was expected to cost $28 million. There were no immediate plans to begin development (Kendall, 1996).

Canada.—Kobitex Inc. distributes Etibanks' refined boron minerals in North America. Included is granular and powdered boric acid, borax penta and deca hydrate from Bandirma, and Etibor-48 and anhydrous borax from Kirka. The products are shipped from Bandirma and Izmir. Kobitex is presently actively supplying products to cellulose insulation, gypsum board, and large chemical distributors. In 1997, Kobitex plans to add fiberglass manufacturers and agriculture companies to its distribution list (Ovi Gulersen, Kobitex Inc., written commun., 1996).

Chile.—Quimica e Industrial del Borax Ltda. (Quiborax) mined from Salar de Surire, the largest ulexite deposit in the world. The salar is located at a 4,250-meter altitude within the border of the Monumento Natural de Surire, a national park in Chile. The ore is trucked to the El Aguila production facility north of Arica. The products are exported from the ports at Arica, Iquiqui, and Antofogasta. The National Boraxx Corp. (Cleveland, OH) packages and distributes boric acid in the United States for Quiborax.

Compania Minera Salar de Atacama (Minsal), is 100% owned by Sociedad Quimica y Minera de Chile SA (SQM). A large integrated facility is planned to began production of 16,000 tons per year of boric acid in 1998 (Chemical Marketing Reporter, 1996a).

Europe.—Starting January 1, 1996, all sales of U.S. Borax Inc. products in Europe are bought, distributed, and sold through Borax Europe Ltd., previously known as Borax Consolidated Ltd. The major change is in the use of a more convenient business system to record orders, keep track of inventory, and plan for delivery to customers. Named BOSS, for Borax Ordering and Sales System, the system is expected to benefit the customer in reducing errors and monitoring orders (Borax Pioneer, 1996d).

India.—Submarginal borax reserves of 74,200 tons have been estimated in thePuga Valley Districts of Jammu and Kashmir. In Rajasthan, the bitterns from Lake Sambhar are reported to contain about 0.5% borax.

Owens-Corning will produce glass-fiber reinforcement in India through a joint venture with the Mahindra Group. A 66-million-pound-per-year plant will be constructed by 1998 in Taloja, north of Bombay (Modern Plastics, 1996).

Japan.—Sumitomo Special Metals Co. announced a production capacity increase in its neodymium, iron, and boron magnets. Sumitomo will install a sintering furnace and machines for cutting and grinding at its wholly owned firm, Kinki Sumitoku Electonics Co., Hyogo Prefecture. Production will be increased from 130 tons to 250 tons per month. The magnets are used in personal computer voice coil motors and air conditioner motors (Intertech Corp., 1997).

Peru.—The Ministry of Energy and Mines published maximum permissible limits for liquid effluents from mining and mineral-processing operations. This is the first standard promulgated under the 1991 mining law for liquid effluents from mining and metallurgical operations. There is one standard for operations started after May 1993 and a second, less stringent standard for operations in existence before May 1993. Arsenic, one of the items for which there is a maximum permissible emissions limit, is commonly found in borate ores (Engineering and Mining Journal, 1996).

Russia.—Primorsky Industrial Amalagmation, in Dalnegorsk, produces boron minerals from datolite containing between 6% and 12% boron oxide. The company is part of the Russian Agricultural Joint Stock Co., known as ROSAGROCHIM. ROSAGROCHIM coordinates the activities of about 100 companies.

Turkey.—Turkey's boron operations are under the control of the Government corporation, Etibank. Ulexite is mined at Bigadic; colemanite at Bigadic, Emet, and Kestelek; and tincal at Kirka. The Bigadic borate district was reported to be the world's largest colemanite and ulexite deposits. Etibank received ISO 9002 accreditation at the Kirka Works and the Bandirma Borax Works plant, where the company refines tincal

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and colemanite ores and concentrates, respectively. Pentahydrate borax (Etibor 48) production capacity is to be expanded 20%, or 40,000 tons per year by 1997. Production capacity of boric acid is reported to be 150,000 tons per year at the Bandirma plant (Chemical Marketing Reporter, 1996b).

The Bandirma Borax and Acid Works produces borax decahydrate, borax pentahydrate, sodium perborate, and boric acid. The Kirka Borax Works produces tincal concentrate, borax pentahydrate, and anhydrous borax.

Emet Colemanite Works, located in Emet District of Kutahya Province, had a production capacity of 700,000 tons per year of run-of-mine ores, both open pit and underground mines. Colemanite ores are processed in a 500,000-tons-per-year concentrator and supplied to domestic and international markets. In 1994, 700,000 tons of colemanite ores and 305,250 tons of colemanite concentrates were produced. Most of the colemanite concentrates are exported. The remaining production is used in the boric acid plant in Bandirma. In 1994, 87,184 tons of colemanite concentrates was sent to the Bandirma boric acid plant.

Bigadic Colemanite Works, located in Bigadic District of Balikesir Province, has a production capacity of 500,000 tons of run-of-mine colemanite and ulexite ores from three open pits and two underground mines. The concentrator has a capacity of 400,000 tons per year that is supplied for export. In 1994, 159,600 tons of run-of-mine colemanite ores and 328,150 tons of run-of-mine ulexite ores were processed. A total of 93,900 tons of colemanite concentrates and 198,200 tons of ulexite concentrates were produced. All products at Bigadic are for export.

Kestelek Boron Mine is located in Mustafakemalpa, a District of Bursa Province. The underground mine was closed at the end of 1994 because of high cost and low sales. Production is now from the open pit. Kestelek Boron is now a subsidiary of Bigadic. In 1994, 115,895 tons of run-of-mine colemanite ore, 19,281 tons of lumpy colemanite, and 37,956 tons of colemanite concentrates were produced for export.

The Kirka Borax Works is located near Seyitgazi District of Eskisehir Province. The concentrator has a capacity of 600,000 tons per year of tincal concentrates. A derivatives facility was begun in 1984 for the production of 160,000 tons per year of borax decahydrate and 60,000 tons per year of anhydrous borax. Technical problems regarding the anhydrous production are being studied. An expansion project was under way to increase pentahydrate production capacity to 320,000 tons per year. There is a storage and loading facility 20 kilometers away at Degirmenozu with a railway connection to the port at Bandirma. In 1994, 783,000 tons of run-of-mine ores, 558,000 tons of tincal concentrates, and 154,449 tons of borax pentahydrate were produced.

In 1994, Bandirma Borax and Acid Works, located in Bandirma District of Bahikesir Province, produced 30,090 tons of borax, 9,273 tons of borax pentahydrate, 46,100 tons of boric acid, and 15,067 tons of sodium borate (Etibank, 1994).

In addition to the Government operations, private processing of boron reserves from stockpiles and dumps have occurred for the past decade.

A comprehensive history of the Turkish boron mines and their impact on the boron industry was published in 1996. Included are the story of the Turkish boron mines and boron industry, Turkey's history, its political system, and its past and present relations with Europe. At the end of the book is a summary of boron applications, geological and mineralogical information, statistics, and other facts and figures useful to those in the boron business (Bühler, 1996).

Current Research and Technology

Ciba Additives acquired the worldwide licenses of 19 patents and patent applications from Mead Corp. in the area of borate photoinitiators. Principal areas of applications include laser imaging, electronic applications, printing plates, resists, and thick sections (Krivyakina, 1996).

A scientist at Harvard University used carbon nanotubes to prepare nanoscale carbide materials using boron carbon in an intermediate processing step. The carbide nanorods might have applications in nanostructured composite materials. Ceramic or metal matrix composites strengthened by embedding rodlike structures that may prove useful in making turbine blades and other aerospace components (Freemantle, 1995).

Scientists in Germany have synthesized a siliconboron carbonitride with high thermal stability, up to 2000° C. The material may be used for the production of ceramic fibers, coatings, and composites that are chemically and mechanically stable at ultrahigh temperatures (Chemical & Engineering News, 1996).

In an effort to build an affordable short-span bridge, Kansas Structural Composites built a traffic-bearing bridge in three sections using fiberglass-reinforced polymer laminate. Fiberglass is one of the chief uses for boron. Recycled polyester resins make up 30% of the bridge weight and were combined with glass fiber to make the core and bottom fiberglass laminate layer (Reisch, 1997).

Outlook

Production of boron minerals and compounds has increased between 1992 and 1996. Production and imports reported in 1 year may be utilized over a period of years. In addition, environmental concerns may change the demand for boron significantly in a short period. The regulation of fire retardants in products has resulted in changes in boron usage as a fire retardant. The 2.6-million-ton-per-year borate products market is growing at about 1.5% per year (Industrial Minerals, 1996b).

Agriculture.—Farming exports are showing increased strength and demand for boron usage in agriculture is expected to increase.

Ceramics and Glass.—Fiberglass, closely related to construction and transportation, was expected to increase. Owens-Corning announced a capacity expansion for the next 3 years in Brazil, the Republic of Korea, Western Europe, and North America. The company projects an annual growth of

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about 5% in North America and Western Europe, and more than 10% in Asia and the Pacific Rim (Modern Plastics, 1996).

PPG Industries forecasts demand for fiberglass reinforcements will be 4.8% over that of 1995. The thermoset market is growing between 150% to 200% times the gross domestic product. The roofing business, for which paper fiberglass is used, has grown more than 10% between 1992 and 1994, and 1996 was expected to see a 4.2% increase in demand over that of 1995. Demand for textile fiberglass grew about 15% in 1994 and is projected to have a 1.9% increase in demand in 1996. The demand for insulation fiberglass is expected to remain flat because of low interest rates. Fiberglass insulation is used primarily in houses, and during times of low-interest rates, housing starts increase, therefore increasing demand for fiberglass (Glass Industry, 1996b).

Coatings and Plating.—Primarily used as a protective coating for steel products and as a glazing on ceramic tiles, boron use is expected to increase.

Fire Retardants.—Demand for borated flame retardants has grown 15% per year. Zinc borate is often used with, or in place of, antimony trioxide. Zinc borate serves as a synergist with chlorine- or bromine-based fire-retardant systems (Chemical Engineering, 1996).

Fabricated Metal Products.—Boron usage in specialized metal was expected to increase.

Soaps and Detergents.—Usage in soaps and detergents was expected to increase 4% per year during the next 5 years.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Sold or used by producers:					
Quantity:					
Gross weight 2/	1,010	1,060	1,110	1,190 r/	1,150
Boron oxide (B2O3) content	554	574	550	728 r/	581
Value	$339,000	$373,000	$443,000	$560,000 r/	$519,000
Exports:					
Boric acid: 3/					
Quantity	80	75	87	75	42
Value	$53,700	$50,500	$53,300	$68,100	$35,300
Sodium borates:					
Quantity	489 4/	481 4/	498 4/	588	381 4/
Value	$159,000 4/	$181,000 4/	$165,000	$227,000	$133,000 4/
Imports for consumption: 4/					
Borax:					
Quantity	16	40	9	9	NA
Value	$5,330	$1,230	$2,700	$936	NA
Boric acid:					
Quantity	6	17	20	16	18
Value	$4,340	$11,900	$12,900	$10,100	$10,800
Colemanite:					
Quantity	30	90	27	45	NA
Value	$16,100	$48,600	$10,800	$8,600	NA
Ulexite:					
Quantity	42	149	120	153	NA
Value	$11,300	$40,700	$24,000	$39,300	NA
Consumption: Boron oxide (B2O3) content	345	321	296	NA	NA
World: Production	2,670	2,690 r/	2,860 r/	2,890 r/	2,980 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Minerals and compounds sold or used by producers, including both actual mine production and marketable products.

3/ Includes orthoboric and anhydrous boric acid.

4/ Source: Bureau of the Census.

TABLE 2
BORON MINERALS OF COMMERCIAL IMPORTANCE 1/

Mineral	Chemical composition	B_2O_3 weight percent
Boracite (stassfurite)	$Mg_6B_{14}O_{26}Cl_2$	62.2
Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	50.8
Hydroboracite	$CaMgB_6O_{11} \cdot 6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7 \cdot 4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19} \cdot 7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9 \cdot 5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2(OH)$	41.4
Tincal (natural borax)	$Na_2B_4O_7 \cdot 10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7 \cdot 5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9 \cdot 8H_2O$	43.0

1/ Parentheses include common names.

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TABLE 3
YEAREND 1996 PRICES FOR BORON MINERALS AND COMPOUNDS PER METRIC TON 1/

Product	Price, Dec. 31, 1995 (rounded dollars)	Price, Dec. 31, 1996 (rounded dollars)
Borax, technical, anhydrous, 99%, bulk, carload, works 2/	794	818
Borax, technical, anhydrous, 99%, bags, carload, works 2/	843	884
Borax, technical, granular, decahydrate, 99%, bags, carload, works 2/	333	381
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works 2/	283	315
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works 2/	374	443
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, works 2/	324	375
Boric acid, technical, granular, 99.9%, bags, carload, works 2/	830	883
Boric acid, technical, granular, 99.9%, bulk, carload, works 2/	780	819
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B2O3, 100-pound-bags, carlots	1,951	1,419
Colemanite, Turkish, 42% B2O3, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC 3/	191	NA
Ulexite, Chilien, 38% B2O3, ground to a minus 6-mesh, f.o.b railcars, Norfolk, VA 3/	257	NA

NA Not available.

1/ U.S. f.o.b. plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

2/ Chemical Marketing Reporter. V. 249, No. 1, Jan. 1996, p. 27; V. 250, No. 27, Dec. 1996.

3/ Bureau of the Census.

TABLE 4
U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY 1/

	1995			1996		
	Boric acid 2/		Sodium	Boric acid 2/		Sodium
Country	Quantity (metric tons)	Value (thousands)	borates 3/ (metric tons)	Quantity (metric tons)	Value (thousands)	borates 3/ (metric tons)
Australia	1,490	$754	6710	1,190	$633	5,040
Belgium	1	9	44	--	--	53
Brazil	2,480	982	1,140	2,590	1,080	1,070
Canada	5,150	3,540	35,600	4,970	3,440	38,300
Colombia	200	197	1,910	78	85	596
France	181	92	83	53	34	29
Germany	114	93	5	141	3,470	13
Hong Kong	585	448	5,060	136	135	3,470
India	--	--	694	--	--	63
Indonesia	1,800	991	12,500	371	222	8,100
Israel	105	88	173	43	32	124
Japan	11,400	10,800	27,600	8,830	8,050	22,300
Korea, Republic of	5,590	3,630	25,800	2,300	1,940	14,600
Malaysia	1,380	796	11,000	222	209	6,660
Mexico	6,700	3,250	18,200	4,210	2,620	15,100
Netherlands	16,400	27,200	329,000	6,630	7,690	198,000
New Zealand	504	262	3,010	225	116	1,620
Philippines	561	226	2,580	9	11	1,390
Singapore	197	149	1,460	557	338	983
South Africa	695	366	1,180	293	162	677
Spain	9,850	8,750	65,800	3,560	1,400	35,900
Taiwan	5,990	3,510	11,700	3,530	2,110	8,350
Thailand	1,380	1,020	7,310	801	637	5,650
United Kingdom	77	113	498	146	141	149
Venezuela	241	180	873	330	233	941
Other	1,450	661	18,500	836	535	11,900
Total	74,500	68,100	588,000	42,100	35,300	381,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ HTS code No. 2810.00.0000.

3/ HTS code Nos. 2840.19.0000, 2840.30.0000, and 2840.20.0000.

Source: Bureau of the Census.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Belgium	2	$2	--	--
Bolivia	989	411	3,460	$1,730
Canada	3	12	6	5
Chile	7,510	3,520	6,310	3,500
France	12	36	8	35
Georgia	42	27	--	--
Germany	11	13	13	35
Italy	1,240	1,290	1,050	1,130
Japan	180	161	110	204
Netherlands	18	11	--	--
New Zealand	--	--	40	25
Peru	471	249	842	510
Russia	438	425	218	186
South Africa	--	--	20	28
Switzerland	--	--	2	1
Turkey	4,670	3,920	5,830	3,420
United Kingdom	4	5	2	3
Total	15,600	10,100	17,900	10,800

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ U.S. Customs declared values.

Source: Bureau of the Census.

TABLE 6
BORON MINERALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Argentina	125	146	215 r/	245 r/	245
Bolivia (ulexite)	18 r/	12	10	7 r/	7
Chile (ulexite)	203	117	86	90 e/	90
China e/ 3/	127	155	188 r/	140	180
Germany (borax) e/	2	2	2	2	2
Iran (borax) e/ 4/	(5/) 6/	1	1	1	1
Kazakstan e/	100	90	80	80	80
Peru	27	37 r/	30 r/	30 r/ e/	30
Turkey 7/	1,059	1,079	1,140	1,100 e/	1,200
United States 8/	1,010	1,060	1,110	1,190 r/	1,150 6/
Total	2,670	2,690 r/	2,860 r/	2,890 r/	2,980

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through May 20, 1997.
3/ B2O3 equivalent.
4/ Data are for years beginning Mar. 21 of that stated.
5/ Less than 1/2 unit.
6/ Reported figure.
7/ Concentrates from ore.
8/ Minerals and compounds sold or used by producers, including both actual mine production and marketable products.

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BROMINE

By Phyllis A. Lyday

The quantity of bromine sold or used in the United States was 227 million kilograms (kg) valued at $150 million. The value of bromine sold or used was 66 cents per kg. Primary uses of bromine compounds were in flame retardants (38%), drilling fluids (22%), sodium bromide solutions (10%), brominated pesticides (mostly methyl bromide) (8%), water-treatment chemicals (7%), and other including photographic chemicals and rubber additives (15%) (Chemical Marketing Reporter, 1997). International distribution of bromine production in 1996 was as follows: The United States, 50%; Israel, 30%; the United Kingdom, 6%; and other countries, 14%. The United States' portion of world production has decreased steadily since 1973, when the United States produced 71% of the world supply. The decrease in world share has been a result of environmental constraints and the emergence of Israel as the world's second largest producer. (*See table 1*).

Legislation and Government Programs

The Food Quality Protection Act was signed into law August 3, 1996, and became effective immediately. The law requires new standards for pesticide tolerances, expanded consumer right-to-know efforts, consideration of a pesticide's benefits, new reviews of minor-use and antimicrobial pesticides, and special consideration of infants and children. The old Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Federal Food, Drug and Cosmetic Act (FFDCA) created a paradox because of the FFDCA's Delaney clause, which had prohibited any trace of a carcinogen in processed food. Pesticide residues in raw commodities, regulated under FIFRA, had no uniform standard, but residues of carcinogens in processed food, which came under FFDCA, even if they posed a negligible risk, were banned because of the Delaney clause, which was added to FFDCA in 1958. Under the new law, the Delaney clause no longer applies (Hanson, 1996).

Methyl bromide continues to be viewed as a significant ozone-depleting compound. Three potentially major anthropogenic sources of atmospheric methyl bromide have been identified (soil fumigation, biomass burning, and the exhaust of automobiles using leaded gasoline), in addition to vaporization from the ocean. Methyl bromide was listed as a Class I ozone depleting substance in the 1990 Clean Air Act, and the chemical is scheduled to be phased out in the United States by January 1, 2001. World participants, at a December 1995 Vienna meeting of the Montreal Protocol, agreed to a world phaseout of methyl bromide by 2010. The Netherlands phased out the use of methyl bromide for soil fumigation in 1992 because of concerns over ground water contamination. Denmark will ban all agricultural uses of methyl bromide in 1998, and Sweden is expected to follow with a similar schedule. The remaining members of the European Union and Canada will cut agricultural uses by 25% in 1998. The final Montreal Protocol agreement also included a production phaseout schedule for industrial nations with a 25% reduction in 2001, a 50% reduction in 2005, and a complete phaseout in 2010. For developing nations, a freeze in 2002 on methyl bromide use will be based on average 1995-98 consumption levels. During the Vienna meeting, the treaty partners elected to defer a decision until 1997 on controlling trade in methyl bromide with countries that have not signed the protocol. This agreement will be revisited in 1997 (U.S. Environmental Protection Agency, Methyl Bromide Information, unpub. data accessed May 8, 1997, on the World Wide Web at URL http://www.epa.gov/doc/ozone/mbr/mb4rqa.html).

Manufacturers of 15 chemicals, including one brominated compound, were asked to provide exposure information to the U.S. Environmental Protection Agency (EPA). The chemicals were selected for the project for various reasons: five were the subject of Toxic Substance Control Act (TSCA) section 8(e) significant risk notices; EPA had information suggesting that two of the substances may pose a cancer threat; and one was a high-production substance suspected of accumulating in the environment. The targeted chemicals are scheduled to be reviewed in EPA's risk management level one program (RM1), the first of two levels of decision making in the agency's program to assess the safety of existing chemicals. The data review could lead to EPA taking action under the TSCA (Chemical Marketing Reporter, 1996k).

EPA fined AmeriBrom Inc., the marketing company for Dead Sea Bromine Co. Ltd. (DSB), $118,000 for failure to register three products. The penalty was 64% less than the fine originally proposed by the agency. The enforcement action included brominating tablets, which are used to control microorganisms in pools and spas (Chemical Marketing Reporter, 1996b).

EPA issued an advance notice of proposed rulemaking that would expand the Toxic Release Inventory (TRI) to require companies that use chemicals in industrial facilities to report information on use, also known as materials accounting. The reporting would be expanded to report on products and waste. The chemical industry objects to diverting the TRI program away from pollution prevention and risk reduction. Emissions are a better indicator of potential health threats to the community. Congress has twice considered and rejected legislation that would require materials accounting, so EPA's legal authority to collect this information is also in question

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(Chemical Marketing Reporter, 1996e).

California's Department of Pesticide Regulation restricted use of methyl bromide in a bill passed in 1996 that allowed manufacturers until December 31, 1997, to complete health studies. Without the legislation, manufacturers said they would not have been able to meet the previous deadline of March 30, 1996. The bill also directed regulators to review restrictions on soil fumigant use of methyl bromide to adequately protect workers and the public from over-exposure (Chemical Marketing Reporter, 1996c).

The Superfund taxes expired in December 1995 and had not been reinstated. Three Senate committees had a plan to take Superfund "offbudget" to ensure that all revenues generated by the program's special taxes on industry are used for hazardous waste site cleanups. Superfund is a trust set up from the taxes on petroleum and chemicals for cleaning up sites where no responsible party with sufficient funds can be found. Unappropriated funds can and have been redirected by lawmakers to pay for other government programs. Placed in a separate account, Superfund taxes would not be subject to the budget rules that apply to spending caps federal lawmakers have imposed on EPAand other Federal agencies. As a result, the money would be for hazardous waste cleaups and could not be used for discretionary spending. Bromine and chlorine, used to produce the bromine, are chemicals taxed to provide funds to Superfund. Since 1981 businesses in the United States have paid more than $12 billion in taxes, including more than $4 billion by the chemical industry. Imported bromine products do not contribute to the tax (Chemical Marketing Reporter 1996j).

The most important regulatory program established under the Clean Water Act (CWA) is the national the National Pollution Discharge Elimination System (NPDES). All point source discharges of pollutants to navigable waters must be authorized by an NPDES permit. In 1987, the CWA was amended to include specific numeric water quality standards for all toxic pollutants which could interfere with the designated uses of streams. NPDES permits issued to the oil and gas industry have become more stringent and complex. Discharge permits for Cook Inlet, AK, provide limitations for chemical additives, such as calcium bromide, sodium bromide, and zinc bromide that are used in completion and work over (upkeep) of oil and gas wells. The 1987 amendments to the CWA emphasized stricter control of toxins in waste water discharges, which State and EPA permit writers have not widely enforced. General permits proposed in 1996 for Region VI discharges into the territorial seas of Louisiana and Region X for coastal and offshore discharges in Alaska are much stricter than previous permits. Region VI and X permits now require numerical water discharge limits. For the oil and gas industry, which has large numbers of facilities in the same geographic area with similar discharges, the EPA has issued general permits. These general permits provide a set of operating and monitoring requirements. The oil and gas extraction industry is divided into five subcategories: offshore, onshore, coastal, agricultural and wildlife water use, and stripper. CWA has a goal of zero discharge of pollutants and no discharge of toxins in toxic amounts. The general permits that have been proposed and issued in 1996 have required major changes in oil and gas industry operations. In some cases, reissued permits have required zero discharge of waste water into streams, such as, in coastal waters of Louisiana and Texas, operators have discharged water produced with oil and gas. A combination of state and EPA measures are leading toward zero discharge of produced water in coastal waters in Louisiana and Texas (Veil, 1997).

The House Ways and Means Committee ordered cancellation of the U.S. International Trade Commission's Quarterly Synthetic Organic Chemicals Report by October 1, 1996. Annual figures will not be available for 1996 and 1995 data will not appear in a finalized form. A private association was considering whether to continue gathering the information (Chemical and Engineering News, 1996).

Production

Domestic production data for bromine were developed by the U.S. Geological Survey from a voluntary survey of U.S. operations. Of the operations to which a survey request was sent, six responded representing 100% of total elemental bromine sold or used. (*See table 2.*)

Albemarle Corp., formerly Ethyl Corp.'s Chemical Division, and Great Lakes Chemical Corp. produced and marketed more than 60 different bromine-based chemicals from plants in Arkansas. Small amounts of unpurified bromine were produced in Michigan as a byproduct in the extraction of magnesium from brine and reprocessed in Arkansas. The Arkansas plants accounted for 96% of U.S. elemental bromine capacity at yearend 1996 and 100% of bromine sold or used. The overall result of the Albemarle expansion program was a bromine production capacity increase of 30% by 1996 (Chemical Marketing Reporter, 1995a).

Albemarle entered a request to find a customer who could use 6,000 pounds (250 gallons) of bromine in custom synthesis in California. (Paul Palmer, CBC/Chemsearch, unpub. data accessed March 27, 1996, on the World Wide Web at URL http://www.sonic.net/chemsearch/enerchem.html).

Great Lakes announced an expansion of a reactive flame retardant capacity for unsaturated polyester resins to be completed by the third quarter 1996 (Chemical Marketing Reporter, 1996g). On November 3, 1995, Great Lakes filed an application with the Arkansas Oil and Gas Commission to establish a third brine production unit consisting of 24,000 hectares (60,000 acres). Under Arkansas law, the company can form a unit if it owns 75% of the mining right to the brine. Murphy Oil Corp., through it subsidiary, Deltic Farm & Timber, filed for a continuance which was granted until the January 28, 1996, meeting. Deltic Farm & Timber, which owns about 4,900 hectares (12,000 acres), filed a lawsuit in U.S. District Court alleging that Great Lakes drained some brines that were owned by Deltic. The law suit also alleges that Deltic wanted to cancel leases that would restrict Great Lakes from having 75% of the leases that it needs for the brine unit. (Arkansas Democrat-Gazette, 1995).

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Great Lakes earned one-half of its operating income, $497 million in 1995, from its tetraethyl lead business (TEL) that uses bromine as a scavanger. TEL is a declining but profitable business in which Great Lakes is the only global company (Chemical Marketing Reporter, 1996h, i).

Ambar Inc. planned to have on-stream in early 1997 a 14-millio- kilogram (30 million pound) elemental bromine facility in Manistee, MI, that will produce elemental bromine and brominated salts. Ambar would be supplied by pipeline with bromine containing brines after production of magnesium hydroxide from Martin Marietta Magnesia Specialties Inc. Ambar planned to manufacture and consume brominated well drilling fluids. Meridian Technologies Inc. was to market additional brominated salts (Chemical Marketing Reporter, 1995d). In July, Ambar was acquired by the Beacon Group Energy Investment Fund LP. Beacon entered into an agreement to purchase the 51% of Ambar currently owned by Randolph M. Moitry, the company's chairman, president and CEO and the 6% of Ambar's shares owned by Kenneth J. Boutle, an Ambar director. No change in Ambar's calcium and bromine plans will reportedly occur as a result of the acquisition (Chemical Marketing Reporter 1996a).

TETRA Technologies Inc. expanded its acreage in Magnolia, AR, from 840 hectares (2,100 acres) in 1988 to 13,355 hectares (33,000 acres) in 1996. In March, a long-term requirement contract that will supply 90% of external calcium bromide needs by the company's worldwide Oil & Gas Services operations was signed with Bromine Compounds Ltd., the largest producer of bromine and brominated compounds in the world. The company previously had held its leases in Arkansas for reserves for the Oil & Gas Service Division, but will now consider other options for the use of the bromine reserves. In 1996, TETRA acquired the clear brine fluids business of Dow Chemical Co. and entered into agreements to purchase crude bromine and build a bromine derivatives facility in Ludington, MI (TETRA Technologies Inc., 1995, 1996).

Consumption

Albemarle listed 2,700 kilograms (6,000 pounds) of bromine in bulk tank on the Chemical Recycling Wide World Web page (Paul Palmer, SBC/Chemsearch Corp., Sebastopol, CA, unpub. data acessed March 27, 1996, on the World Wide Web at URL http://www.sonic.net/chemsearch/). The bromine was listed as being available for custom synthesis but Special Department of Transportation permitted tanks and nickel or lead lined vessels are required to transport the bromine.

The majority of swimming pools in the United States and Canada are sanitized with chlorine, but more pools are switching to bromine compounds each year. A large number of spas already use bromine compounds. Liquid, elemental bromine forms hypobromous acid and hypobromite ions when added to water. Because of the handling problems with elemental bromine, only compounds of bromine are used for water disinfection. Bromine cannot be protected from ultra-violet light, so it is impractical to use elemental bromine for use in outdoor pools. The tablets used in outdoor pool sanitizing contain bromine and chlorine. The chlorine is used to oxidize the bromine to produce the acid and ions. Hypobromous acid destroys bacteria, algae, or other organisms, or is decomposed by sunlight to a bromide ion, which can be reactivated by adding an oxidizer. The hypobromous acid can combine with ammonia and nitrogen compounds in the water to form bromamine that is an active sanitizer and is less odoriferous than chloramines. Therefore, in pools sanitized with bromine compounds, the chlorine odor does not exist, although it is necessary to periodically oxidize the organic waste to prevent buildup and irritation to skin and eyes (R. Chamberlin, Absolute Spa Services, Port Moody, BC, Canada, unpub. data accessed July 12, 1996, on the World Wide Web at http://www.infomatch.com/spaguy/wtrbal.html bromine).

Many government regulations, insurance company requirements, building codes, and voluntary industry standards define when and where flame-retardant chemicals must be used. Except where government standards exist, such as automotive and airplane components and in the State of California for mattress upholstery materials, the decision to use a flame-retardant resides with the manufacturer. Flame-retardants grew during 1995, indicating that more manufacturers are using flame-retardant additives, such as bromine. Business Communications Co. market research indicated bromine based flame-retardants had 32% of the $718 million market in 1995 (Reisch, 1997).

Foreign Trade

The General Agreement on Tariffs and Trade (GATT) was signed into law in December 1994 and took effect January 1, 1995. GATT lowered chemical tariffs by an average of 30%. Chemicals, including bromine, are the Nation's largest export commodity, as more than 10 cents out of every export dollar is a product of the chemical industry. The agreement's intellectual property provisions include greater patent protection for products developed by American firms. GATT changes patent enforcement from 17 years from the date of issue to 20 years from the date of application. Patents issued on applications filed before June 8, 1995, will be enforceable for either 17 years from the issue date or 20 years from the filing date, whichever is longer. (*See tables 3 and 4.*)

World Review

France.—France's sole producer of potash at Mines de Potasse d'Alsace, S.A., part of State-owned chemicals group Entreprise Miniere et Chimique, operated two underground mines near Mulhouse in eastern France that produced byproduct bromine. Mines de Potasse d'Alsace will phase out all the French Government involvement in the operation by 2004. Marketing is through the trading subsidiary Socíeté Commerciale de Potasse et d'Azote (Leblond, 1994). (*See table 6.*)

Israel.—Bromine has been produced as a byproduct from

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waste bitterns associated with potash production from the Dead Sea since 1957 by Dead Sea Works (DSW). After potash is removed in solar ponds, the waste bitterns are processed with chlorine to recover bromine. The bromine-free bitterns are then processed to recover magnesium.

The Israeli Government began efforts in 1985 to sell a share of Israeli Chemical Co. Ltd. (ICL) to offset an investment program. ICL split Dead Sea Bromine Co., Ltd. (DSB) from DSW and retain an 89% share in DSB. The other 11% of DSB is owned by the public through stock on the Tel Aviv stock exchange. On October 11, 1994, the Israeli government published a tender for the sale of 25% of ICL to a single investor or group of investors. Israel Corp. (IC), Tel Aviv, bought a 24.9% share of the ICL during 1995. IC will pay $230 million for the ICL stake. The family of Israeli business executive Shoul Eisenberg controls 50% of IC and 50% is owned by an offshore corporation Eisenberg also controls. The Government will continue to hold a 27.1% share in ICL after completion of the international offering.

ICL is a group of chemical and mineral industrial companies, with research institutes, technical facilities, and commercial and marketing services. Recovery of potash salts on a commercial scale from the Dead Sea first began in 1931. The soluble minerals exist mainly as chloride and bromine anions and magnesium, sodium, and potassium cations. Crude carnallite is harvested and the waste brines are processed for magnesium chloride and bromides. Approximately 70% of ICL's activities are devoted to the fertilizer industry, including the production of raw materials and intermediates. Current production includes potassium chloride, magnesium chloride, magnesium oxide, magnesium metal, chlorine products, bromine, caustic soda, salt, uranium, lanthanides, radium sulfate, monocalcium phosphate and/or calcium nitrate and hydrochloric acid (Lin and Schorr, 1996; Phosphorus & Potassium, 1996).

DSB production capacity for bromine, after the expansion at Sdom was 190,000 tons per year. The increase in capacity required the purchase of isotank containers. DSB has enough isotank capacity to ensure the transportation of exported bromine.

DSB has production plants at Sdom and Ramat. A 50-50 joint venture between Great Lakes and DSB came on-stream during 1996 to manufacture a flame retardant used primarily in epoxy circuit board production and other resin applications. Although demand was down when the plant came on stream, demand in the electronics industry increased at yearend. The $22 million flame retardant plant at Ramat planned to reach capacity by 1998. Each partner of the joint venture, Tetrabrom Technologies Ltd., will market the product separately (Chemical Marketing Reporter, 1996d). Tetrabrom could eventually represent 25% of world flame retardants capacity (Chemical Marketing Reporter, 1995b).

Jordan.—Arab Potash Co. Ltd. and Albemarle were negotiating to form a joint-venture company to produce bromine from potash waste brines; ownership of the company was expected to be distributed 51% and 49%, respectively. The new company is called the Jordan Industrial Chemicals of the Dead Sea Minerals Co. The decision to form the company follows a memorandum of understanding with Albemarle for construction of a 50,000-ton-per-year plant. The investment in the plant would be $145 million, and the plants are to be operational by 1997 (Green Markets, 1994).

Dead Sea Bromine group and Jordan's Arab Potash Corp. Signed a memorandum of understanding to construct a $50 million bromine plant on the Jordanian side of the Dead Sea. The 50-50 joint venture would be managed by the Jordanians and built with technical assistance by DSB. The plant was expected to be operational by 1998 (Chemical Marketing Reporter, 1995c).

Keir International, United Kingdom, has won a $13.8 million contract to build a brine water intake system at the Dead Sea for Arab Potash Co. The project will include the constuction of a 200-meter jetty supporting twin 2-meter diameter pipes for extracting brine to potash (Phosphorus & Potassium, 1995).

Turkmenistan.—A conference on the production capacities of working mines and processing enterprises of Turkmenistan listed bromine production at the Nebitdagh Iodine Factory at 3,200 tons of ferrous bromide and the Cheicken Chemical Factory at 6,400 tons of ferrous bromide (Turkmenistan Ministry of Energetics and Industry and others, 1996).

World Bank.—A world phaseout of leaded gasoline to reduce health problems in developing countries has been proposed by the World Bank. The bank believes phasing out lead could be carried out within 5 years at a cost of about 2 cents per liter. The bank is urging nations still using leaded gasoline to reduce the lead content to 0.15 grams per liter or less. All leaded gasoline contains a bromine compound that is used as a scavenger so this action would cause a decrease in the use of bromine. The bank is promoting lead phaseout schedules and financial packages through loans and guarantees to attract private investments to finance the change (Crow, 1996).

Current Research and Technology

The rate constants and equilibrium saturation capacity for the gold-bromide species are higher than those reported for the gold-cyanide system. The rate of loading increased with decreasing particle size, decreasing pH, increasing temperature, and decreasing concentration of gold in solution (Mensah-Biney, R., Reid, K.J., and Hepworth, M.T., 1996).

Stratigraphic profiles of bromine distribution from analyses of 3,045 salt samples in Colorado and Utah indicated that 29 of the salts were deposited from seawater. Averages of bromine values show variations that indicate potash and halite were concentrated in the deeper parts of the basin and other salts and carbonate rock are thicker toward the basin margins. There is a positive correlation between halite beds that have high levels of bromine and those that contain potash deposits. Bromine distribution, therefore, is a valuable tool in exploration for potash deposits in evaporites of marine origin (Raup and Hite, 1996).

The 35th Biennial Congress for the International Union for Pure and Applied Chemistry presented a program that covered

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six different fields of chemistry. In the field of inorganic chemistry and solid state, there were five plenary lectures, one of which covered bromine chemistry in the atmosphere related to human activities. Recent measurements reveal that in the lower stratosphere (16-20 kilometers altitude) the effect of nitrogen oxides on ozone is outweighed by reactions of hydrogen containing radicals, such as bromine monoxide (BrO). The release of nitrogen radicals at those altitudes actually decreases the loss of ozone, because the nitrogen radicals react with the ozone destroying radicals, thereby short circuiting their destructive effect. It is estimated that nearly one-third of the photochemical loss of ozone is due to chlorine- and bromine-monoxides (Chemistry International, 1996).

Between 6.8 to 9 million kilograms (15 to 20 million pounds) of methyl bromide are used each year in California, primarily for preplant soil fumigation. Although methyl bromide is important to agriculture its absence would have a small effect on most of California's agriculture. The United Nations Methyl Bromide Technical Options Committee concluded that alternatives exist or are at an advanced stage of development for more than 90% of methyl bromide use (James Liebman, Pesticide Action Network North American Regional Center, San Francisco, CA, unpub. data accessed on May 8, 1997, on the World Wide Web at URL http://www.cdpr.ca.gov/doc/dprdocs/methbrom/mb4chg.html).

Researchers at the University of California, Riverside, proposed methyl iodide as a replacement for methyl bromide in soil fumigation (S. R. Yates, U. S. Salinity Laboratories, Riverside, CA, unpub. data accessed May 8, 1997, on the World Wide Web at URL http://www.ars.usda.gov/is/mba/april96/yatest.html). However, there is little information regarding methyl iodide's behavior in agricultural soils. It is important that any decision to use alternative fumigants should balance environmental consequences and economic implications. Because methyl iodide has a longer half-life, this may cause delays in planting. If the soil needs venting to reduce photo-toxicity, an increase in total emissions into the atomsphere related to methy bromide may result.

Dr. Vincent Patrick in consultation with the Australian Minerals Industry Reserach Association developed a low-toxicity heavy liquid called LST that can replace bromoform and tetrabromoethane chemicals traditionally used to separate minerals from gangue. The low-viscosity aqueous solution is made of tungsten polyanions and uses acetone and alcohol. LST should prove attractive to companies producing diamonds, mineral sands, industrial ores, and heavy metals like tantalum and tin (Australian Science & Technology Newsletter, 1996).

Molybdenum trioxide studies with bromine polymers produce more char than chlorine type polymers in the solid phase of the fire. Char has been found to restrict the spread of fire by removing the fuel source. Few aromatic products were formed (Musselman, 1996).

Outlook

Petroleum.—Demand for bromine as a gasoline additive has declined each year since the EPA issued regulations in the 1970's to reduce the lead in gasoline. In the United States bromine, in the form of ethylene dibromide or EDB, is used as a "scavenger" for the lead to keep the lead from depositing in the engine. In 1979, the amount of bromine sold reached a peak of 225 million kilograms. The rapid decline to 141 million kilograms in 1986 was a direct result of the limits on lead in leaded gasoline. The European Community continued discussions to reduce lead levels in gasoline. Bromine in petroleum additives is expected to continued to decline over the long-term. Federal laws enacted to encourage alternative forms of power in automotive engines are likely to have a depressive effect on bromine demand. The Clean Air Act Amendments of 1990 have an amendment that will require mobile sources, such as cars and trucks, to use the most effective technology possible to control emission. Electric cars that do not require bromine gasoline additives are already on the market in California.

Sanitary Preparations.—Bromine has found usage in indoor swimming pools, hot tubs, and whirlpools. The sanitary preparation field is an area where bromine has been found to be safer than its substitutes because bromine has a higher biocidal activity level for the same amount of product. Applications in the pulp and paper industry, in cooling towers, and Government-regulated food-washing applications are growth areas. The use of bromine will continue to grow in sanitary preparation, closely following the gross national product in real growth.

Fire Retardants.—A study by Business Communications Co. (BCC) expected the domestic flame-retardant industry to reach sales of $924 million by the year 2000. Bromine-based flame-retardant chemicals are expected to grow at a 6.4% annual average growth rate. BCC states flame retardancy represents bromine's largest domestic use (Chemical Marketing Reporter, 1996f).

Other Uses.—Usage of calcium, sodium, and zinc bromides in well-drilling fluids decreased during the 1980's as the domestic petroleum industry suffered a severe recession. Oil field chemicals used in drilling, completion and work over, and production operations have remained significantly more profitable internationally than in the United States. The competition market included corrosion inhibitors, bactericides, viscosities and defoamers, as well as commodities such as calcium chloride and calcium bromide brines used to maintain well productivity. Because of the significant benefits of bromine compounds in the well-drilling fluids area, usage is expected to grow at the rate of 2% per year.

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TABLE 1
SALIENT BROMINE AND BROMINE COMPOUNDS STATISTICS 1/

(Thousand kilograms and thousand dollars)

	H.T.S.U.S. 2/ Number	1992	1993	1994	1995	1996
United States:						
Bromine sold or used: 3/	--					
Quantity		171,000	177,000	195,000	218,000	227,000
Value		$125,000	$123,000	$155,000	$186,000	$150,000
Exports: 4/ 5/						
Elemental bromine:	2801.30.2000					
Quantity		5,320	6,010	6,470	3,220	2,920
Value		$5,540	$7,440	$7,270	$3,790	$3,970
Bromine compounds: 6/	(7/)					
Gross weight		20,000	15,800	13,700	13,300	13,100
Contained bromine		16,900	13,400	11,500	11,200	1,110
Value		$26,400	$21,800	$21,100	$19,900	$22,100
Imports: 4/ 8/						
Elemental bromine:	2801.30.2000					
Quantity		851	850	319	2,220	415
Value		$522	$513	$194	$1,460	$305
Bromine compounds:						
Ammonium bromide:	2827.59.2500					
Gross weight		1,790	1,240	1,120	288 9/	11,700 10/
Contained bromine		1,460	1,010	917	235 9/	9,370 10/
Value		$2,870	$2,020	$1,850	$832 e/ 9/	$9,580 10/
Calcium bromide:	2827.59.2500					
Gross weight		5,370	9,650	14,700	730 9/	--
Contained bromine		4,290	7,720	11,700	584 9/	--
Value		$3,210	$3,740	$5,380	$262 e/ 9/	--
Potassium bromate:	2829.90.0500					
Gross weight		407	280	166	275	462
Contained bromine		195	134	79	132	221
Value		$1,250	$892	$538	$933	$1,750
Potassium bromide:	2827.51.0000 11/					
Gross weight		883	1,180	1,280	171 9/	NA
Contained bromine		592	790	858	115 9/	NA
Value		$1,660	$2,170	$2,270	$420 e/ 9/	NA
Sodium bromate:	2829.90.2500					
Gross weight		176	290	276	944	1,200
Contained bromine		93	153	146	500 r/	634
Value		$469	$725	$714	$2,360	$3,030
Sodium bromide:	2827.51.0000 11/					
Gross weight		1,100	1,270	1,400	1,400 r/ 9/	NA
Contained bromine		852	983	1,090	1,070 9/	NA
Value		$1,620	$1,730	$1,770	$2,550 r/ e/ 9/	NA
Other compounds:	2903.30.1550					
Gross weight		11,700	12,500	14,300	5,850 r/ 12/	6,520
Contained bromine		7,160	7,600	8,680	4,880 r/ 12/	5,090
Value		$21,500	$36,500	$42,600	NA	$14,900
World: Production: e/		397,000	396,000	412,000	432,000	452,000

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits.

2/ "Harmonized Tariff Schedule of the United States".

3/ Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.

4/ Bureau of the Census.

5/ Export values are "Free-alongside-ship" (f.a.s.).

6/ Bureau of the Census. Includes methyl bromine and ethylene dibromide.

7/ Data for these compounds are derived from HTSUS numbers 2903.30.0500 and 2903.30.1500 information.

8/ Import values are "Cost, insurance, and freight" (c.i.f.).

9/ The Journal of Commerce Port Import/Export Reporting Service.

10/ The respective data for "Bromides/Bromines and Oxides" of Ammonium, Calcium and Zinc are combined and reported here.

11/ "Bromides of sodium" or of "'potassium" import data are usually reported by a mutual HTSUS number, 2827.51.0000.

12/ Certain compounds reported for 1995 are not included in the total.

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TABLE 2
ELEMENTAL BROMINE-PRODUCING PLANTS IN THE UNITED STATES, 1996

State and company	County	Plant	Production source	Capacity 1/ (million kilograms)
Arkansas:				
Albemarle Corp.	Columbia	Magnolia	Well brines	120
Arkansas Chemicals, Inc.	Union	El Dorado	do.	25
Great Lakes Chemical Corp.	do.	do.	do.	70
Do.	do.	Marysville	do.	60
Michigan:				
The Dow Chemical Co.	Mason	Ludington 2/	do.	15
Total 3/		(Plants) 5		290

1/ Actual production capacity is limited by brine availability.
2/ Bromine produced at this plant is reprocessed in Arkansas.
3/ Chemical Marketing Reporter, Vol. 251, No. 13, p. 37.

TABLE 3
YEAREND 1996 PRICES 1/ FOR ELEMENTAL BROMINE AND SELECTED COMPOUNDS

Product	Value (Cents) Per pound	Per kilogram
Ammonium bromide, National Formulary (N.F.), granular, drums, carlots, truckloads, f.o.b. works	110 - 131	242 - 289
Bromine:		
Drums, truckloads, works 2/	123	271
Bulk, tank cars, works 2/	56 - 68	123 - 150
Bromochloromethane, drums, bulk, f.o.b. Magnolia, AR	127	280
Ethyl bromide, technical, 98%, drums, truckloads	127	280
Ethylene dibromide, drums, carloads	57	126
Hydrobromic acid, 48%, drums, carloads, truckloads, f.o.b.	42	93
Hydrogen bromide, anhydrous, cylinders, 2,500 pounds, truckloads	475	1,047
Methyl bromide, tank cars	77	170
Potassium bromate, granular, powdered, 200-pound drums, carloads, f.o.b. works	179	395
Potassium bromide, N.F., granular, drums, carloads, f.o.b. works	110 - 112	242 - 247
Sodium bromide, technical, truckloads	70	154

1/ Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. Vol. 250, No. 27, Dec. 30, 1996, pp. 20-27.
2/ Delivered prices for drums and bulk shipped west of the Rocky Mountains, 1 cent per pound higher. Bulk truck prices 1 to 2 cents higher per pound for 30,000-pound minimum.

TABLE 4
U.S. IMPORTS OF OTHER BROMINE COMPOUNDS 1/ 2/

Compounds	H.T.S.U.S. 3/ Number	1995 Gross weight (kilograms)	1995 Value 4/ (thousands)	1996 Gross weight (kilograms)	1996 Value 4/ (thousands)	Principal sources, 1996
Hydrobromic acid	2811.19.3000	125	$143	179	$215	Israel 78%; Netherlands 22%.
Ethylene dibromide	2903.30.0500	836	599	3	43	United Kingdom 100%.
Methyl bromide	2903.30.1520	3,540	4,470	3,530	6,230	Israel 100%.
Dibromoneopentyl glycol	2905.50.3000	--	--	1,000	3,480	Do.
Tetrabromobisphenol A	2908.10.2500	8	NA	349	699	Israel 95%; Netherlands 5%.
Decabromodiphenyl oxide and octabromodiphenyl oxide	2909.30.0700	1,340	3,050	1,460	4,190	Israel 100%.
Total		5,850 r/ 5/	NA	6,520	14,900	

r/ Revised. NA Not available.
1/ These data detail the information included in table 1, imports of "Other Bromine Compounds".
2/ Data are rounded to three significant digits.
3/ Harmonized Tariff Schedule of the United States.
4/ Declared c.i.f. valuation.
5/ Certain compounds reported in 1995 are not included in that year's total.

Source: Bureau of the Census.

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TABLE 5
WORLD BROMINE ANNUAL PLANT CAPACITIES 1/ AND SOURCES, DECEMBER 31, 1996

Country and company	Location	Capacity (thousand kilograms)	Source
Azerbaijan:			
Neftechala Bromine Plant	Baku	5,000	Underground brines.
China:			
Laizhou Bromine Works	Shandong	30,000	Do.
France:			
Atochem	Port-de-Bouc	13,600	Seawater.
Mines de Potasse d'Alsace S.A.	Mulhouse	2,300	Bitterns of mined potash.
India:			
Hindustan Salts Ltd.	Jaipur	1,500	Seawater bitterns from salt production.
Mettur Chemicals	Mettur Dam		
Tata Chemicals	Mithapur		
Israel:			
Dead Sea Bromine Co. Ltd.	Sdom	190,000	Bitterns of potash production from surface brines.
Italy:			
Societa Azionaria Industrial Bromo Italiana	Margherita di Savoia	900	Seawater bitterns from salt production.
Japan:			
Toyo Soda Manufacturing Co. Ltd.	Tokuyama	20,000	Seawater.
Spain:			
Derivados del Etilo S.A.	Villaricos	900	Do.
Turkmenistan			
Nebitag Iodine Plant	Vyshka	3,200	Underground mines.
Cheicken Chemical Plant	Balkan	6,400	Do.
Ukraine			
Perekopskry Bromine Plant	Krasnoperckopsk	3,000	Do.
United Kingdom:			
Associated Octel Co. Ltd.	Amlwch	30,000	Seawater.

1/Excludes U.S. production capacity. See table 2.

TABLE 6
BROMINE: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country 3/	1992	1993	1994	1995	1996
Azerbaijan	5,000	4,000	3,000	2,000	2,000
China	16,650	24,600 r/	31,400 r/	30,000 r/	30,000
France	3,200 4/	2,290	2,190 r/	2,260 r/	2,200
Germany	– r/	– r/	– r/	– r/	–
India	1,300	1,400	1,400	1,500	1,500
Israel	135,000	135,000	135,000	135,000	135,000
Italy	300	300	300	300	300
Japan	15,000	15,000	15,000	15,000	15,000
Spain	250	200	200	200	200
Turkmenistan	12,000	10,000	8,000	7,000	7,000
Ukraine	7,000	5,000	4,000	3,500	3,000
United Kingdom	29,903 4/	27,423 4/	33,800 r/	26,200 r/	28,000
United States 5/	171,000 4/	177,000 4/	195,000 4/	218,000 4/	227,000 4/
Total	397,000	402,000 r/	429,000 r/	441,000 r/	451,000

r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through Apr. 24, 1997.
3/ In addition to the countries listed, several other nations produce bromine, but output data are not reported; available general information is inadequate to formulate reliable estimates of output levels.
4/ Reported figure.
5/ Sold or used by producers.

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CADMIUM

By Peter H. Kuck and Jozef Plachy

In 1996, two companies produced primary cadmium (Cd) in the United States. These companies, one in Illinois and one in Tennessee, recovered the cadmium as a byproduct of the smelting and refining of zinc (Zn) concentrates. A third company, in Pennsylvania, recovered cadmium from spent nickel-cadmium (Ni-Cd) batteries. Based on the average New York dealer price, the combined output of primary and secondary metal in 1996 was valued at $4.2 million. The estimated consumption pattern included batteries, 67%; pigments, 14%; coatings and plating, 8%; stabilizers for engineering plastics and similar synthetic products, 8%; nonferrous alloys, 2%; and other, including electrooptics, 1%.

To date, cadmium recycling has been practical only for Ni-Cd batteries, some alloys, and dust from electric arc furnaces—the latter typically containing 0.003% to 0.07% Cd. At the beginning of 1996, 13 of the 50 States had laws regulating Ni-Cd's and other rechargeable batteries. Nine of the thirteen States also required the collection of rechargeable batteries. The Portable Rechargeable Battery Association (PRBA), a nonprofit trade association, composed of over 100 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries was in the process of setting up a nationwide collection and recycling system.

The United States, as in most years, was a net importer of cadmium metal in 1996; so far this decade, it has been a net exporter only in 1994-95. The major import sources over the last 5-year period, 1992-96, have been Canada, 43%; Belgium, 13%; Mexico, 12%; and Germany, 7%. Cadmium compounds and pigments are subject to import duties, but unwrought and powdered metal, as well as waste and scrap, enter duty free in all but a few cases. At yearend, 2,034 metric tons of unwrought cadmium metal were held in the National Defense Stockpile, all of it authorized for sale or previously committed.

The U.S. dealer price for cadmium, which was characterized by considerable volatility in the last decade, fell in 1996 to two-thirds of the 1995 price.

Cadmium was refined in 32 countries in 1996. The three largest refiners—Japan, Canada, and Belgium—together accounted for 34% of world production, compared with 8% for the United States.

Identified world cadmium resources at yearend 1996 were estimated by the U.S. Geological Survey at 6 million tons, a figure based on zinc resources containing typically about 0.3% cadmium. The world reserve base was estimated at 970,000 tons and reserves at 540,000 tons. The United States has 22% of the world reserve base and 13% of the reserves. The United States, Canada, and Mexico, together, have 43% of the world reserve base and 34% of the reserves.

Legislation and Government Programs

In 1994, legislation was introduced in the Congress to make the reclamation of spent consumer batteries [i.e., household batteries, batteries for portable office equipment, and batteries for electric vehicles (EV's)] more economically feasible and remove regulatory burdens from the battery recycling industry. A modified version of the legislation pertaining specifically to Ni-Cd batteries was taken up again by the 104th Congress, passed, and signed into law by the President on May 13, 1996. The new law was entitled "The Mercury-Containing and Rechargeable Battery Management Act of 1996" (Public Law 104-142). Title I of the act established uniform national labeling requirements for Ni-Cd, small sealed lead-acid, and certain other regulated batteries. Each battery or battery pack must bear a recycling symbol and a recycling phrase appropriate to its electrode chemistries. The labeling requirements are similar to ones already adopted by Japan. Domestic battery manufacturers and importers must be in complete compliance with the labeling requirements by May 1998. Title I also provided for the streamlining of regulations governing battery collection and recycling. Voluntary industry programs are to be encouraged, and regulatory requirements are to be minimized so that the collection and recycling programs can be efficient and cost-effective. Title II of the act phases out the use of batteries containing mercury.

The U.S. Environmental Protection Agency (EPA) is responsible for enforcing most of the provisions of the act. EPA can now promulgate regulations requiring manufacturers of rechargeable consumer products to redesign their products, if safety is not compromised, so that the batteries inside can be more easily removed. The agency also has been directed to work with battery manufacturers, manufacturers of consumer products, and retailers in disseminating proper handling and disposal information on batteries to the general public. The legislation had the support of most battery manufacturers and many retailers.

On December 13, 1996, the President of the United States signed an executive order designed to encourage the use of EV's and other alternative fueled vehicles (AFV's) in metropolitan areas of the country (Presidential Documents, 1996). Executive Order 13031 (Federal Alternative Fueled Vehicle Leadership) requires each federal agency to immediately develop and implement plans for acquiring alternative fueled vehicles. In fiscal year (FY) 1997, 33% of the general-use vehicles acquired were to be AFV's. This percentage increases to 50% in FY 1998, 75% in FY 1999, and 75% for subsequent years. The executive order was designed to reduce U.S. dependence on

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imported oil, provide an economic stimulus to domestic industry, and improve air quality in various parts of the country. Some industry analysts expect the order will spur production of nickel-metal hydride, advanced lead, and lithium-ion batteries for EV's in the United States. The effect of the order on the use of enhanced Ni-Cd batteries in U.S. vehicles was uncertain. No U.S. automobile manufacturer has announced plans to introduce a Ni-Cd powered automobile in the near future. However, Ni-Cd batteries are being used in at least one Japanese and two European models. Ni-Cd batteries offer some advantages over advanced lead competitors in terms of reliability, longevity, energy density, and recyclability. Ni-Cd batteries also have the potential to capture a large part of the market for electric motor scooters, electric bicycles, and electric wheelchairs. Tokyo R&D Co. Ltd. recently began selling a Ni-Cd powered electric scooter, which retails in Japan for ¥596,000 or about $5,030.

The Defense Logistics Agency (DLA) continued to sell sticks and balls of cadmium metal from the National Defense Stockpile as part of the huge downsizing of the stockpile approved under the Defense Authorization Act of 1992 (Public Law 102-484). When DLA began offering cadmium on March 22, 1993, there were 2,871 metric tons (6,328,570 pounds) of the metal in DLA warehouses. By the beginning of 1996, uncommitted stocks had shrunk to 2,020 tons (4,452,635 pounds). An additional 230 tons (506,533 pounds) were turned over to purchasers during the year, leaving uncommitted stocks of 1,920 tons (4,232,048 pounds) on December 31, 1996. Total yearend stocks also included 114 tons (250,373 pounds) of committed material.

Production

Most of the virgin cadmium currently being recovered around the world is a byproduct of zinc smelting and refining. The cadmium is associated with the zinc in concentrates of sphalerite and related sulfide ore minerals. It is also recovered during the beneficiation and refining of some lead ores or complex copper-zinc ores.

Only two companies produced primary cadmium in the United States in 1996: Big River Zinc Corp., Sauget, IL; and Savage Zinc Inc., Clarksville, TN. Both companies operated electrolytic zinc plants and recovered the cadmium as a byproduct precipitate after the zinc concentrates were roasted and leached.

In April 1996, Korea Zinc Co. Ltd. purchased Big River Zinc and the Sauget smelting and refining operation from its owner, Dillon Read & Co., for $52.5 million. The Sauget operation can produce up to 82,000 tons of zinc and 900 tons of cadmium per year and has been receiving about 80% of its feedstocks from mines in Missouri and Tennessee. The remaining 20% was being imported, largely from Canada, Mexico, and Peru (Mining Journal, 1996). Korea Zinc will provide technical expertise and financial support to improve production at Sauget. The Korean company is currently capable of producing about 215,000 tons of zinc, 135,000 tons of lead, and 550 tons of cadmium per year at its Onsan complex in Kyungsang-Namdo Province. Korea Zinc has agreed to construct a world-class lead-zinc smelting and refining complex at Townsville, Australia. (*See section on Australia.*)

Savage Zinc Inc. was preparing to expand its Clarksville smelting and refining operation in north-central Tennessee and was in the process of obtaining the necessary permits (Savage Resources Limited, 1996). Some 60% to 70% of the operation's feed comes from three underground zinc mines operated in the central and eastern part of the State. The balance is provided by ASARCO Incorporated, which operates four underground zinc mines in the Mascot-Jefferson City District northeast of Knoxville. Since Savage acquired the Tennessee operation in May 1994, the company has had an active exploration program in the State, particularly at its Gordonsville Mine east of Lebanon. The program has increased proved and probable ore reserves significantly. On June 30, 1996, Savage's three mines had combined reserves of 25.3 million tons grading 3.1% Zn. Most of the byproduct cadmium recovered at Clarksville was being sold domestically. The refinery's germanium residues continued to be shipped to Olen, Belgium, for eventual recovery by Clarksville's previous owner, the Union Minière Group. Asarco temporarily suspended operations at its New Market Mine near Strawberry Plains in Jefferson County because of declining ore grades and low zinc prices.

The cadmium recovery facilities at Asarco's Globe refinery in Denver, CO, were idle the entire year. Asarco shut down its cadmium line in spring 1993 and has no immediate plans to produce cadmium domestically.

On December 28, 1995, International Metals Reclamation Co., Inc. (INMETCO) began reclaiming cadmium from spent batteries at its high temperature metals recovery plant in Ellwood City, PA. The first heat of cadmium metal was poured on December 30, 1995, and cast into shot. The $5 million cadmium addition was the only facility of its kind in the world and was built for INMETCO by Davy International. The metal, which has a purity greater than 99.95% Cd, was being shipped to Ni-Cd battery manufacturers for reuse. Some of the production runs have assayed as high as 99.999% Cd. The cadmium is made in the form of small flattened discs, 4 to 6 millimeters in diameter, to facilitate handling and reduce erratic rolling (Hanewald, Schweers, and Liotta, 1996).

The Ellwood City facility received more than 2,700 tons of spent Ni-Cd batteries from municipal authorities and industry in 1996 (International Metals Reclamation Co. Inc., 1997). The spent batteries reportedly had an average cadmium content of 12% to 15%. The company was also accepting nickel-metal hydride (Ni-MH) and nickel-iron batteries, but asked that the two be segregated from the Ni-Cd's whenever feasible. Shipments from Motorola Inc., Black & Decker Inc., and other electronic appliance manufacturers tend to be relatively free of lead and other less desirable metals. However, batteries collected from the general public require considerable attention. At the present time, small sealed lead acid batteries and other nonconforming batteries have to be removed by hand prior to processing. Many of the spent batteries are more than 5 years

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old. Only a few of the newer batteries are color coded and almost none carry bar codes, making optical scanning and other automated sorting difficult to impossible.

The Ellwood City facility was set up in 1978 to reclaim chromium, nickel, and iron from a variety of wastes generated by specialty steelmaking operations in Canada and the United States. In 1996, in addition to cadmium, INMETCO produced about 21,400 tons of chromium-nickel-iron alloy containing 15,100 tons of iron, 3,400 tons of chromium, 2,600 tons of nickel, and 330 tons of molybdenum. In the past, all of this material would have been disposed of in landfills. INMETCO is a subsidiary of Inco Ltd., the second largest producer of nickel in the world.

The proposed Crandon Mine in northeastern Wisconsin is expected to be a significant source of cadmium by the year 2005. The massive sulfide deposit is about 9 kilometers south of Crandon, the seat of Forest County. The deposit contains an estimated 61 million tons of ore grading 5.6% Zn and 1.1% Cu (Lambe and Rowe, 1987). Pyrite is ubiquitous throughout most of the deposit. Sphalerite is the second most abundant sulfide and a major constituent of the massive ores, forming laminae interbedded with pyrite laminae in mineralized sedimentary beds. Lesser amounts of sphalerite also occur in some of the chalcopyrite-rich stringer ores of the footwall. Electron microprobe analyses of sphalerite from different parts of the deposit revealed that the cadmium content of the sphalerite is highly variable, ranging from less than 0.01% to 0.23% Cd (Lambe and Rowe, 1987). Sphalerite from one particular stratigraphic sequence—the Skunk Lake unit—consistently has the highest cadmium values, averaging 0.09% Cd.

In 1996, the Crandon Mining Co. completed development of its environmental impact report for the proposed underground zinc-copper mine (Tanner and Evans, 1997). The Wisconsin Department of Natural Resources was reviewing the report and scrutinizing models that might reveal potential disturbances in groundwater flow. The Crandon Mining Co. is a joint venture of Exxon Minerals Co. and Rio Algom Ltd. During the year, the joint venture signed agreements with the Town of Nashville, the Town of Lincoln, and Forest County that addressed issues of local concern. Exxon began exploring Wisconsin for massive sulfides in 1969 and discovered the Crandon deposit in 1975 when it drilled a promising electromagnetic anomaly near Skunk Lake. The original Exxon project was shelved in 1986 because of unfavorable economic conditions.

Environment

Cadmium is considered toxic, particularly in soluble and respirable forms, and must be handled with care. Although cadmium commonly is associated with zinc, the two behave somewhat differently in biological systems. Zinc is an essential element in almost all biological systems and plays important roles in metalloenzyme catalysis, metabolism, and the replication of genetic material. Cadmium, on the other hand, can adversely affect the renal and respiratory systems, depending upon exposure time and concentration, and is not readily excreted. Inhaled cadmium fumes or fine dust are much more readily absorbed than ingested cadmium. Repeated exposure to excessive levels of dust or fume can irreversibly injure the lungs, producing shortness of breath and emphysema. Dermal contact with cadmium results in negligible absorption. The International Agency for Research on Cancer lists cadmium metal and several of its compounds as carcinogens.

The incineration of plastics containing cadmium pigments and stabilizers is of greater concern in the European Union (EU) than in the United States. Landfilling, which locks up the cadmium, is not a viable option in the Benelux countries and other parts of Europe where the population density is extremely high and geologically secure sites are limited. Health and safety regulations in the EU prohibit or discourage manufacturers of flexible polyvinyl chloride (PVC), polyurethane, and other polymers from incorporating cadmium-based heat stabilizers in their products (Koot, 1996). The Netherlands and several other EU member countries also recently banned the use of cadmium pigments in most virgin engineering plastics. Exemptions permit the recycling of some cadmium-containing plastic waste, such as damaged bottle crates. Another major concern has been the amount of cadmium being released into the atmosphere by the combustion of coal and other fossil fuels.

A cadmium workshop and a followup session on risk reduction were held in Saltsjöbaden, Sweden, from October 16 to 21, 1995. The workshop was held under the auspices of the Organisation for Economic Co-operation and Development (OECD) and was cosponsored by the Swedish National Chemicals Inspectorate and the Dutch Ministry of Housing, Spatial Planning and Environment. The proceedings of the workshop were published in two monographs (Organisation for Economic Co-operation and Development, 1996a, b). The first monograph discusses sources and pathways of cadmium in the environment, while the second focuses on ways to limit or reduce the cadmium content of fertilizers. More than 12 anthropogenic sources of cadmium were reviewed at the Saltsjöbaden workshop, including: the burning of fossil fuels, municipal waste incinerators, base metal smelters, iron and steel works, cement plants, liming materials, phosphate fertilizers, other soil amendments, and sewage sludge.

Several member countries of the EU were especially concerned about cadmium levels in phosphate rock being imported into Europe for agricultural purposes and took the opportunity to lobby for more restrictive limits on the cadmium content of all fertilizers and municipal composts. Some EU regulatory agencies and environmental groups are worried that long-term use of high-cadmium fertilizers could cause the toxic metal to accumulate in the soil and be taken up by edible plants, inadvertently entering the food chain (Roberts, 1996). In an effort to head off regulation, the European Fertilizer Manufacturers Association has voluntarily agreed to limit cadmium levels in their products to 60 milligrams Cd per kilogram of phosphorus pentoxide (P_2O_5) by the year 2005. A few fertilizer producers are working on technologies to extract cadmium from phosphate rock, but most processes evaluated to date are either uneconomical or have serious limitations. Four

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of the more promising processes for removing cadmium from phosphoric acid are: (1) cocrystallization of cadmium with anhydrite, (2) precipitation with inorganic sulfide salts, (3) formation of complex cadmium chloride anions and subsequent removal by anion exchange, and (4) removal by solvent extraction (Davister, 1996; Vermeul, 1996). Austria, Belgium, Denmark, Finland, Norway, Sweden, and Switzerland already restrict cadmium levels in phosphate fertilizers—with maximum allowable concentrations ranging from 22 milligrams Cd per kilogram P_2O_5 for Finland and Switzerland to 120 milligrams for Austria. Japan has a higher limit of 150 milligrams.

As part of the agreement, European fertilizer producers will switch suppliers, importing only feedstocks that fall below the new 60 milligram limit. Countries such as Senegal and Togo that mine phosphate rock with elevated levels of cadmium may have increasing difficulty marketing their production. Phosphate rocks from some of their competitors contain considerably less cadmium (e.g. Florida, the Kola Peninsula of Russia, and Phalaborwa, South Africa). Phosphate rocks of igneous origin normally contain less than 15 milligrams Cd per kilogram P_2O_5 compared with 20 to 245 milligrams for their sedimentary counterparts (Davister, 1996). Rock from Nauru has some of the highest cadmium levels found to date and averages 243 milligrams Cd. In 1996, the principal ocean shippers of phosphate rock (in descending order) were Morocco, Jordan, Togo, and Israel (SSY Consultancy and Research Ltd., 1997). U.S. exports of phosphate rock have fallen off dramatically since 1991. All five countries mine sedimentary phosphate deposits.

U.S. research agronomists argued at Saltsjöbaden that the risk of transferring cadmium from the soil to humans via the food-chain is not as serious as some regulatory authorities perceive (Chaney and others, 1996). Considerable emphasis has been placed on cadmium uptake studies carried out on rice plants during the 1970's and 1980's in China and Japan. These studies showed that rice grown in paddies contaminated by zinc mine wastes had abnormally high levels of cadmium and that the cadmium-rich rice, in turn, was responsible for certain rare kidney and bone diseases afflicting the subsistence farmers and their families who depended upon the rice as their principal food source. Soils with as little as 2 milligrams of Cd per kilogram dry weight had adverse health effects on the subsistence farmers. However, subsequent studies found that the farmers had diets that were seriously deficient in iron, zinc, and calcium which increased intestinal absorption of the cadmium. New evidence indicates that cadmium disease is not observed under similar conditions when exposure is via the vegetable food chain. Garden crops grown in the United Kingdom on soils contaminated with 50 to 150 milligrams Cd per kilogram and 5,000 to 15,000 milligrams Zn per kilogram did not induce cadmium disease. Rice is apparently a very atypical plant in terms of cadmium uptake. In most plants, the uptake of cadmium is strongly affected by the cadmium to zinc ratio in the soil. As a general rule, zinc inhibits cadmium uptake. The addition of small amounts of zinc fertilizer to the soil can solve many cadmium accumulation problems. Soil pH, clay content, and soil chloride levels also have a significant influence on uptake of the metal. Tobacco is a second atypical plant that presents special environmental risks (Chaney and others, 1996). Smokers tend to have higher kidney cadmium levels than nonsmokers.

Consumption

Apparent consumption of cadmium metal in the United States nearly doubled between 1995 and 1996. This increase was due largely to growing demand for Ni-Cd batteries throughout North America—producing a sharp drop in exports of both the unwrought metal and scrap. The rapidly expanding U.S. program for recycling industrial and household batteries has encouraged electronics manufacturers to continue to use Ni-Cd batteries in their products and even incorporate the batteries in future project designs. The U.S. Geological Survey (USGS) did not collect actual consumption data on either cadmium metal or cadmium compounds. However, for some time, the International Cadmium Association has been making annual estimates on an end use basis for the Western World. Their breakdown for 1996 was as follows: batteries, 70%; pigments, 13%; stabilizers for plastics and similar synthetic products, 7%; coatings and plating, 8%; and alloys and other, 2% (Morrow, 1997). This breakdown differs somewhat from the USGS series quoted earlier for just the United States. Consumption patterns vary significantly within the OECD membership because of differences in environmental regulations, industrial development, natural resources, and trading partnerships. Relatively small but critical amounts of cadmium metal, alloys or compounds are frequently incorporated into solar cells, radiation detectors, lasers, and other electro-optical devices.

The traditional uses of cadmium in easily dispersible products continued to decline in OECD countries because of increasingly stringent environmental regulations, concerns of manufacturers about long term liability, and the development of less toxic substitutes. Environmental activists in the EU have been lobbying for further restrictions on the use of cadmium in such products. The use of cadmium in electroplating, plastics additives, and pigments has diminished significantly over the last two decades.

Cadmium compounds are still being used in the United States and the Far East to stabilize PVC. Liquid stabilizers typically contain 1% to 8% Cd in the form of cadmium 2-ethylhexanoate or cadmium oleate. Solid stabilizers contain 4% to 12% Cd in the form of salts of saturated fatty acids (e.g., stearic acid and lauric acid). The cadmium content of the finished PVC article usually contains no more than 0.2% Cd. The cadmium is locked into the polymer matrix and has extremely low leachability (Donelly, 1996). Still, cadmium-based stabilizers are banned in Sweden. The EU as a whole currently restricts certain uses of cadmium-based stabilizers and is encouraging the replacement of barium/cadmium systems by barium/zinc or other alternatives wherever technically feasible.

In contrast, the use of cadmium in rechargeable batteries has steadily grown over the same time period. Ni-Cd batteries are

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widely used in handheld power tools and a myriad of portable electronic devices, including compact disc players, pocket recorders, camcorders, cordless telephones, cellular telephones, scanner radios, and laptop computers. Two French automobile manufacturers—PSA Peugeot-Citroën and Renault—began limited production of Ni-Cd powered EV's in 1996. The batteries for the vehicles were being manufactured by SAFT S.A. at its new battery plant in Bordeaux, France. In 1996, the United States imported $673 million worth of Ni-Cd batteries. The bulk of the imported batteries were made in Mexico, Japan, China, or Hong Kong (in descending market share).

Cadmium metal forms stable alloys with copper, tin, and several other nonferrous metals. When aluminum, brass, copper, and steel are coated with cadmium metal, they become much more resistant to corrosion, especially in marine and alkaline environments. Few elements are superior to cadmium for coating and plating if cost and corrosion resistance are weighed equally. From 1940 until 1988, coatings and plating constituted the largest use of the metal in the United States.

Since 1965, consumption of cadmium for coatings and plating has declined more than 70% in the Western World because of human health and environmental concerns about the metal (Morrow, 1996). In 1990, coatings and plating accounted for only 9% of total cadmium consumption in Europe and a mere 1% in Japan. That same year, the corresponding figure for the United States was estimated to be 25%. Since 1965, the U.S. plating industry has taken a number of steps to make cadmium coatings more acceptable. A series of surveys by The Cadmium Council, Inc. (now part of the International Cadmium Association) found that occupational exposures in most cadmium plating shops were below the Action Level of 2.5 micrograms of cadmium per cubic meter of air set by the Occupational Safety and Health Administration, with many shops having levels equal to or less than 1.0 micrograms of cadmium per cubic meter of air. Plating wastewater must now be treated to remove any cadmium and other heavy metals before the water can be discharged. Electroplating sludges are no longer landfilled and are being shipped to EPA-approved reclamation facilities for metal recovery. In 1996, at least three facilities were licensed to receive cadmium-bearing electroplating sludges for reclamation: INMETCO, Horsehead Resources Development Corp., and Encycle Inc.

U.S. industry took these steps because cadmium plating is still required for applications where the surface characteristics of the coating are critical (e.g., fasteners for aircraft, electrical connectors, parachute buckles). Cadmium coatings do not oxidize as readily as zinc coatings in marine or concentrated salt atmospheres and have lower relative coefficients of friction, making for smoother surfaces. Cadmium coatings also have low electrical resistivity and good soldering characteristics. In 1992, the communications sector accounted for 31% of the cadmium coatings market in the United States (Morrow, 1996). The next three largest applications were fasteners (20%), aircraft (15%), and automotive (15%).

Cadmium pigments are more stable than organic coloring agents at elevated temperatures and are not easily degraded by light. Because of their excellent coloring properties, cadmium pigments are widely used in thermoplastics, ceramics, glazes, and artists' colors. When cadmium sulfide is mixed in differing amounts with cadmium selenide and related inorganic pigments, a broad spectrum of brilliant colors with strong opacity can be generated. Organic alternatives still cannot match many of the more popular properties of cadmium pigments, especially color brightness, opacity and processability.

A significant amount of cadmium was still being used worldwide to make colorants for plastics, despite regulatory pressures. The U.S. colorant and pigment industry has restructured almost every aspect of production in response to the new Federal and State regulations. Many producers of plastic colorants had planned to phase out cadmium along with barium, chromium, and lead in order to make their products more environmentally acceptable. However, for some applications there was no organic alternative on the market that could match the brilliant yellow provided by a cadmium pigment. Replacement of key cadmium pigments by organic substitutes is not straightforward, especially for molding applications that require high temperature or pressure processing. Organic substitutes are not as stable and are more difficult to work with under these conditions.

Rhône-Poulenc of France has begun marketing a new family of cerium sulfide pigments that both overcomes the limitations of organic substitutes and completely sidesteps growing concerns about the recycling and ultimate disposal of plastics containing cadmium-based pigments (Industrial Minerals, 1995). Limited quantities of the new pigments are being produced at the company's Roches-Roussillon plant near Lyon, France, and are being sold under the Neolor trademark to the plastics industry. Both red and orange pigments are available, and Rhône-Poulenc is planning to expand the color range into the yellow part of the spectrum. In June 1994, Ferro Corporation, a U.S.-based supplier of inorganic pigments, agreed to help develop and distribute the Neolor pigments in the United States and Canada (Tourre, 1997).

Less than 1% of the cadmium consumed annually is used in electro-optics. However, cadmium plays an extremely critical role in this increasingly important end use because, to date, few other semiconducting materials have been able to satisfactorily substitute for cadmium compounds in key applications. Although small, these electro-optical devices can be costly to manufacture and have become extremely sophisticated technologically. Zinc sulfide powder activated with silver was one of the first materials used as a scintillator to detect and electronically count the alpha particles emitted during the radioactive decay of uranium and the other actinides. This early work led to the development of cadmium sulfide photoconductive films for lighting controls and eventually to small, liquid-nitrogen-cooled cadmium telluride semiconductor detectors for gamma-ray spectrometry. Today, a number of types of infrared photon detectors, blue/violet/ultraviolet lasers, and solar cells utilize some form of cadmium. Omnichrome Corp. of Chino, CA, and LiCONiX of Santa Clara, CA, were two of several companies that manufactured helium-cadmium

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laser systems. One successful use of the violet/ultraviolet laser was to create parts in stereolithography. Besides imaging, the lasers have a wide variety of other applications in medicine, biology, nondestructive testing, and forensic science.

After silicon and gallium arsenide, mercury cadmium telluride is one of the more important general purpose semiconductors. For more than 30 years, mercury cadmium telluride ($Hg_{1-x}Cd_xTe$) has been the semiconductor of choice for mid- and long-wavelength infrared photodetectors (Piotrowski and Perry, 1997). The material has a high specific detectivity (i.e., signal-to-noise ratio) for infrared photons, especially in the spectral range of 3 to 30 micrometers—an important region of the electromagnetic spectrum for remote temperature sensing and thermal imaging. The spectral cutoff of the detector can be shifted within this region for optimal detection by tailoring the chemical composition of the cadmium alloy. The x value in the formula is normally set somewhere between 0.17 and 0.50. The $Hg_{1-x}Cd_xTe$ absorber (i.e., the layer within the device that absorbs the infrared radiation) is grown, using epitaxial techniques, on a substrate of cadmium telluride, cadmium zinc telluride, or silicon metal. Infrared photodetectors have proven extremely useful for mapping the earth's surface at night because infrared photons scatter much less in the lower atmosphere than photons of visible light. For the same reason, related devices are useful to the U.S. Department of Defense for missile guidance and for detecting targets from high altitudes. More down to earth uses include pyrometers, instrumentation for analytical chemistry, laser radiation monitors, night-vision equipment, and burglar alarms.

Prices

Prices weakened significantly in 1996, dropping back to 1994 levels. The New York dealer price for metal, published by *Metals Week* for the week ending January 5, 1996, ranged from $1.90 to $2.00 per pound. The monthly average price for January was $1.90, slightly higher than the 1995 annual average of $1.84. However, the price began to weaken in February and continued to spiral downward for the rest of the year. Prices were even weaker during the first half of 1997. For the week ending December 27, 1996, the New York dealer price ranged from $0.80 to $0.92. The average annual price for 1996 was $1.24.

Some industry analysts attribute the extreme volatility of cadmium prices to the fact that only about 5% of the cadmium shipped from producers is actually sold on a spot basis. The remaining 95% is sold under long-term contracts which depend on price feedback from the spot market. This system amplifies the weight of published price changes associated with limited spot sales, making it relatively easy for speculators to influence the market. The growing importance of recycled cadmium in the marketplace is expected to dampen this amplification and promote price stability (Morrow, 1997).

World Review

Industry Structure.—World refinery production of cadmium was estimated at 18,900 tons in 1996. Canada replaced Japan as the largest producer of refined cadmium products. Belgium edged out the United States for third place.

Capacity.—World cadmium refining capacity was estimated at 23,000 tons. Almost 40% of this capacity was in Europe or Central Eurasia.

World Resources.—Existing resources of cadmium should be adequate to meet demand far into the 21st century. For the near term, the principal source will continue to be concentrates of sphalerite. Australia has the world's largest demonstrated resources of cadmium—an estimated 190,000 tons contained in 95 million tons of sphalerite. Canada is a close second with about 170,000 tons contained in 83 million tons of sphalerite.

Australia.—Three new zinc mines and one electrolytic zinc refinery were in varying stages of development, increasing Australia's capacity to recover cadmium. Feasibility studies were being conducted on several other zinc projects, most of which were in Queensland or Western Australia. The McArthur River Mine was officially opened on September 6, 1995, but was still in the startup phase. The new zinc-lead-silver mine is near Borroloola in the northeast corner of the Northern Territory, about 100 kilometers south of the Gulf of Carpentaria. The underground mine is controlled by MIM Holdings Ltd. (70% equity) and has an annual production capacity of 160,000 tons of zinc and 45,000 tons of lead. More than one-half of the cadmium-bearing concentrates were being shipped to MIM's smelters in Germany and the United Kingdom, with the remainder going to custom smelters in Australia, Europe, and Japan. The capacity of the Woodcutters Mine—also in the Northern Territory—was being expanded from 70,000 tons of zinc per year to 97,000 tons. The Woodcutters Mine is owned by Normandy Metals Ltd. The Cannington Mine, being developed by BHP Minerals Ltd. near Cloncurry, Queensland, was scheduled to start up in 1997. The Cannington Mine has 45 million tons of ore reserves averaging 11.1% zinc.

The permitting and land acquisition process for the Century Zinc project at Lawn Hill in northwest Queensland was delayed by litigation over aboriginal rights to the property. Part of the concentrates from the proposed Century mill were to go to a custom smelter operated by Pasminco Ltd. at Budel-Dorpein in the Netherlands. The Century deposit was being developed by the giant Rio Tinto Zinc Corp.-Conzinc Riotinto of Australia (RTZ-CRA) and reportedly had 188 million tons of ore grading 10.2% zinc. In late 1996, RTZ-CRA pulled out of the project and sold both the Century deposit and the Dugald River zinc deposit to Pasminco for $275 million. Pasminco needs the low-iron concentrates from the Century Mine to meet limits that Dutch environmental authorities have placed on generation of waste jarosite at the Budel smelter. In 1996, Budelco B.V. produced 603 tons of cadmium.

Korea Zinc was to begin construction of the world's largest zinc smelting and refining complex in late 1996. The complex was to be built at Townsville, Queensland, and would initially

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produce 170,000 tons per year of zinc metal for the export market. More than 300 tons of byproduct cadmium would be recovered annually at the refinery. The capacity of the $375 million complex was to be doubled by the year 2005.

China.—In April 1996, a new electrolytic zinc refinery was commissioned at the Zhuzhou smelting complex in Hunan Province. The Government-owned lead-zinc complex has been in operation since 1959. The new refinery raised the electrolytic zinc capacity of the complex from 150,000 tons of zinc per year to 250,000 tons. At least 40% of the output was special high grade zinc destined for export. The expansion was expected to increase cadmium production to 800 tons per year. Both 99.99% and 99.95% Cd grades were being marketed, with sticks and balls being made in preference to ingot to take advantage of the price differential. Domestic mines provide about 95% of Zhuzhou's feed (Metal Bulletin, 1996c).

European Union.—Italy.—The state-owned resources group, Enirisorse SpA, has decided to privatize its lead-zinc mining, smelting, and refining operations in southwestern Sardinia. The lead and zinc concentrates used as feed are currently being imported. At one time, a large part of the concentrates came from the group's Masua and Monteponi Mines at Iglesias, but the output from these mines has fallen off dramatically since 1992 because of depleted reserves. The zinc is recovered at Porto Vesme in an Imperial Smelting Furnace and upgraded in an adjoining electrolytic refinery. The lead is recovered at Porto Vesme by the Imperial Smelting Process and the Kivcet Process. Enirisorse also has a lead refinery at San Gavino. Together, the two complexes produce about 300 tons of cadmium annually and have a combined annual capacity of about 160,000 tons of zinc and 120,000 tons of lead (Metal Bulletin, 1996b).

Enirisorse also has invited tenders for the purchase of its only other electrolytic zinc refinery—at Crotone on the eastern coast of Calabria—which has an annual capacity of 100,000 tons of zinc. The Crotone facility was commissioned in 1928 and was being run by a subsidiary, Pertusola Sud SpA. The operation had been recovering byproduct germanium and indium in addition to cadmium. In 1995, Italy produced 308 tons of cadmium metal, down significantly from a 7-year high of 742 tons in 1992.

Japan.—Japanese production of cadmium declined from 2,652 tons in 1995 to 2,343 tons in 1996. The 11% decrease was due to the closure of the Barajima electrolytic zinc refinery, near the port of Akita in Akita Prefecture. The refinery's owner, Mitsubishi Materials Corp., shut down the operation after it became more economical to import zinc metal, rather than to recover it from domestic and imported concentrates.

Japan continued to be the world's largest consumer of cadmium. About 87% of Japanese production is consumed domestically, with the remainder going primarily to China and the Republic of Korea. The 1996 decline in Japanese production was offset by increased imports of unwrought cadmium, in descending order, from Belgium, Canada, and Australia. In 1994, Japan consumed 7,131 tons of cadmium. An estimated 6,675 tons (or 94%) of the 7,131 tons was used in the manufacturing of Ni-Cd batteries (Fujimoto and Mukunoki, in press).

Kazakstan.—The lead-zinc industry recovered 1,200 tons of cadmium in 1996, almost the same tonnage as in 1995, largely as a byproduct of zinc refining. The typical sphalerite ores in Kazakstan contain about 0.007% Cd. Most of the ore came from mines operated by the Leninogorsk Polymetal Combine, the Ust-Kamenogorsk Lead-Zinc Integrated Works, and the Zyryanovsk Lead Combine. On November 29, 1996, the Government of Kazakstan announced that the three mining and metallurgical enterprises would be incorporated into a single stock company, Aktsionernoye Obschestvo Katztsink. The consolidation was to take effect in January 1997. Equity in the new company was to be divided as follows: Leninogorsk, 30.2%; Zyryanovsk, 27.5%; Ust-Kamenogorsk, 27.3%; and the Government of Kazakstan, 15%. The three enterprises are located within 300 kilometers of one another and are already connected by rail.

Peru.—On February 15, 1995, Cominco Ltd. and Marubeni Corp. jointly purchased the electrolytic zinc refinery at Cajamarquilla. The refinery is about 20 kilometers east of Lima and recovers significant cadmium as a byproduct. Cominco owns 82% of the shares of the holding company—Sociedad Minera Refinería de Zinc de Cajamarquilla S.A. Marubeni has 17% of the shares, with the refinery employees controlling the remaining 1%. Cominco is responsible for day-to-day operations and also provides technical and marketing support. The Cajamarquilla refinery was built in 1981 and is designed to produce up to 102,000 tons of zinc per year. The refinery operated at full capacity in 1996, making 105,400 tons of zinc—a new production record (Cominco Limited, 1996). Cadmium production was 279 tons, up 6% from 263 tons in 1995. In 1995, zinc production was only 80,800 tons because of problems with three of the refinery's four power transformers. Since then, two new transformers have been brought in from Canada and the older transformers have been refurbished.

The consortium was planning to spend $30 million in 1997 to raise the capacity of the refinery to 120,000 tons of zinc per year, increasing cadmium production accordingly. A study was underway to determine if it was feasible to double Cajamarquilla's output to 230,000 tons of zinc per year. All of the concentrate feed for Cajamarquilla comes from Peruvian mines, which currently produce four times more concentrate than the country's two refineries can process. The second refinery is at La Oroya and has an annual capacity of 70,000 tons of zinc.

Current Research and Technology

In France, PSA Peugeot Citroën and Renault began manufacturing Ni-Cd powered EV's on a limited scale. Peugeot Citroën, an alliance of Automobiles Peugeot and Automobiles Citroën, is Europe's third largest manufacturer of conventional automobiles. Peugeot Citroën currently has three EV models in production: the Peugeot 106 Electrique, the Citroën AX Electrique, and the Tulip. To date, the alliance has produced

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more than 1,000 standard Peugeot 106 and Citroën EV's. The Tulip is a small special two-seater EV designed to complement existing urban transit systems. The alliance is also producing a Ni-Cd battery-powered scooter that can attain a speed of 45 kilometers per hour.

During World War II, Peugeot developed a small three-wheeled EV to alleviate gasoline rationing. This vehicle was the forerunner of two prototype EV models introduced in 1989: the Peugeot J5 and the Citroën C25. For more than 6 years, Peugeot Citroën has been field testing some 50 EV's at the Atlantic port of La Rochelle. A network of recharging stations was set up around La Rochelle as part of the experiment. Peugeot formally introduced its new 106 Electrique in 1995. The two-door hatchback has three battery packs of 6-volt Ni-Cd monoblocks. The three packs (a total of 20 monoblocks in series) provide 120 volts to a direct current motor. The Ni-Cd batteries were being serviced by the manufacturer, SAFT SA, which has a brand new Ni-Cd battery manufacturing facility in Bordeaux. The 106 Electrique has a driving range of 80 kilometers and can accelerate from 0 to 50 kilometers per hour in 8.5 seconds (PSA Peugeot Citroën, 1997). The EV retails for $18,150.

In October 1996, British sponsors bought 14 Electrique's and were field testing them in the Midlands city of Coventry (Simonian, 1996). The handful of hatchbacks and vans were being used by the Coventry City Council, East Midlands Electricity, PowerGen, and the Royal Mail.

In 1994, Peugeot Citroën joined Générale de Transport et d'Industrie (GTI) and Cegelec to form the LISELEC Group, a futuristic EV rental company. The group is currently testing 10 Electrique's in the Paris region and is planning to set up a fleet of EV's for self-service operation throughout the region. Each LISELEC customer would be issued a pass and an associated personal code that would permit him or her to pick up an EV at any one of a network of parking stations and return it to any station of his or her choice. GTI, which operates public transit systems in 87 French towns, is responsible for designing the overall system and managing the parking stations. Cegelec will design and manufacture the necessary electronic door locks, the keyless ignition control, car phone, and charging terminals. Cegelec will also provide the central control system and the on-line computerized reservation/invoicing equipment. The Tulip would be the first rental EV used in the LISELEC system and is specially designed for this purpose. The vehicle is equipped with an on-board computer that communicates with the central control station. The Tulip network has the potential to dramatically improve the flexibility and net earnings of most metropolitan transit systems and could prove to be a major end use for cadmium.

Outlook

The future of the cadmium industry is tied to the development of new recycling technologies. A global system for recycling Ni-Cd batteries is rapidly becoming a reality. However, effective recycling systems still do not exist for some of the other principal end products. These new systems must be viable, resilient, economical, and—above all—be able to allay the environmental and health concerns that the general public currently has about the metal and its compounds. The proper disposal of damaged plastics, obsolete electronic parts, incinerator residues, and municipal sewer sludge—all of which often contain relatively low levels of dispersed cadmium—is still a problem. The U.S. cadmium industry already has taken a number of steps to minimize occupational exposure and has upgraded its facilities so that almost all more than meet the new Federal standards adopted since 1992.

The market for Ni-Cd batteries is expected to grow at least 6% per year over the next 10 years even if American automobile manufacturers decide not to put Ni-Cd cells in their new electric vehicles. Ni-Cd batteries are strong contenders for the rapidly growing electric scooter/bicycle market and will still be used in rechargeable power tools, home appliances, and other household equipment because of cost constraints. Ni-Cd batteries continue to compete head-on with Ni-MH and lithium-ion alternatives in the portable electronics sector. However, over the last 3 years, lithium-ion and Ni-MH batteries have been gaining ground against nickel-cadmium for some electronic end uses. In Japan, Ni-MH batteries have already captured 49% of the office equipment market, 18% of the communications market, and 7% of the home applications market (Fujimoto and Mukunoki, in press).

The U.S. collection and recycling program for small rechargeable batteries is in a period of rapid expansion. The program is administered by the Rechargeable Battery Recycling Corporation (RBRC), a nonprofit public service corporation. RBRC generates revenue for the program by licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. More than 175 companies are currently participating in the program. PRBA is also a sponsor and has helped to enlist the participation of county and municipal governments, hospitals, and fire departments. Spent Ni-Cd, Ni-MH, lithium-ion, and small sealed lead batteries are all being collected under the program. The program is now operating in 19 States at more than 4,500 retail locations. Some 300 counties also have drop-off centers. RBPRC believes that, by the year 2001, roughly 70% of the spent Ni-Cd batteries being generated in the United States will be recycled. The current recycling rate is about 15%. An estimated 85% of industrial Ni-Cd batteries are recycled. INMETCO was expecting receipts of spent Ni-Cd batteries in 1997 to be 20% to 25% greater than those of 1996. If the new RBRC program grows as expected, INMETCO could be handling 10,000 tons of batteries by the year 2002.

A similar program exists in Japan. There, the program is being promoted by the Japan Storage Battery Association (JSBA), which represents 11 battery manufacturers. In 1994, 880 million Ni-Cd cells were sold in Japan. Statistics collected by the JSBA indicate that 33% of the cells went into cellular telephones and other communications equipment. Another 27% went into home appliances (VCRs, shavers, etc.). The third

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largest market was power tools, which accounted for 15%.

Spent Ni-Cd batteries are being recycled by at least nine foreign plants (Metal Bulletin, 1996a). The largest foreign recycler is Sté. Nouvelle d'Affinage des Métaux S.A.R.L. (SNAM), which has two plants in France—one at Viviez in the Massif Central region and another at St. Quentin Fallavier near Lyon. Together, the two recover about 650 tons of cadmium annually (Broad, 1997). SNAM is also responsible for the SAFT NIFE AB recycling operation in Sweden, which recovers about 225 tons. In Japan, the collection system supervised by JSBA feeds spent batteries into four regional recycling plants: Japan Recycle Center (3,000 tons of batteries per year), Mitsui Mining Co., Kansai Catalyst (500 tons per year), Mitsui Mining Co., and Toho Zinc Co. Ltd. (an electrolytic zinc refiner receiving 1,700 tons per year). Retailers, waste collectors, product manufacturers, and more than 1,900 municipalities all participate in the program (Fujimoto and Mukunoki, in press). The Japanese system is currently recovering about 600 tons per year of cadmium. Other foreign recyclers include Hydrometal SA (Belgium), Uniquel SA (Spain), and TNO/Esdex (Netherlands).

On March 29, 1996, the California Air Resources Board (CARB) unanimously approved a staff recommendation to restructure the board's electric vehicle mandate. The staff recommendation was based in part on the findings of an independent battery technical advisory panel. CARB still wants to have 800,000 EV's and other zero-emission automobiles on California highways by the year 2010. However, the board has decided to drop its earlier requirement that seven leading automobile manufacturers begin selling EV's in California in 1998.

The old regulation would have required 2% of all automobiles sold in California to be EV's or some other type of zero-emission vehicle. This percentage was to escalate to 5% beginning with the 2001 model year. The two requirements were dropped after the auto manufacturers requested additional time to resolve technological problems. The auto manufacturers are particularly concerned that the limited range of existing EV prototypes will seriously limit their marketability. In exchange for being released from the 1998 requirement, the manufacturers have agreed to meet the existing 10% requirement for the year 2003 and to begin selling low-emission vehicles–the so-called 49-State car–in the 2001 model year. The board directed its staff to draw up a memorandum of agreement between the State of California and each of the seven automobile manufacturers. Special credits will be issued to manufacturers who market EV's before 2003.

If domestic auto manufacturers decide to incorporate Ni-Cd batteries into some of their EV models, U.S. consumption of cadmium could soar. This scenario may never materialize, though, if existing Ni-MH and lithium-ion battery manufacturing processes can be successfully scaled up. No existing technology can presently meet all of the performance requirements established for EV's by the United States Advanced Battery Consortium. Projections by the International Cadmium Association suggest that world auto manufacturers may build 160,000 Ni-Cd powered EV's in the year 2003. The cells for these vehicles would require 6,000 tons of cadmium—about one-third of present world refinery production.

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TABLE 1
SALIENT CADMIUM STATISTICS 1/

(Metric tons, cadmium content, unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production of metal 2/	1,620	1,090	1,010	1,270	1,530 p/
Shipments of metal by producers 3/	2,070	1,320	1,290	1,280	1,310 p/
Exports of metal, alloys, and scrap	213	38	1,450	1,050	201
Imports for consumption, metal	1,960	1,420	1,110	848	843
Stocks of metal, Government, yearend	2,870	2,690	2,480	2,260	2,030
Apparent consumption	3,270	3,010	1,040	1,160	2,250
Price, average per pound, New York dealer 4/	$0.91	$0.45	$1.13	$1.84	$1.24
World: Refinery production	19,800 r/	19,000 r/	18,500 r/	18,900 r/	18,900 e/

e/ Estimated. p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits, except prices.
2/ Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
3/ Includes metal consumed at producer plants.
4/ Price for 1 to 5 short-ton lots of metal having a minimum purity of 99.95%.

TABLE 2
U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

Year	Cadmium sulfide 1/	Other cadmium compounds 2/
1995	105	936
1996	119	720

1/ Includes cadmium lithopone and cadmium sulfoselenide.
2/ Includes oxide and plating salts (acetate, carbonate, nitrate, sulfate, etc.).

TABLE 3
SUPPLY AND APPARENT CONSUMPTION OF CADMIUM 1/

(Metric tons)

	1995	1996
Industry stocks, Jan. 1	423	542
Production	1,270	1,530
Imports for consumption, metal	848	843
Shipments from Government stockpile excesses	214	230
Total supply	2,750	3,140
Exports of metal, alloys, and scrap	1,050	201
Industry stocks, Dec. 31	542	693
Consumption, apparent 2/	1,160	2,250

NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Total supply minus exports and yearend stocks.

TABLE 4
INDUSTRY STOCKS, DECEMBER 31

(Metric tons)

	1995		1996	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	139	W	360	W
Compound manufacturers	82	321	120	214
Distributors	W	(1/)	W	(1/)
Total	222	321	479	214

W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."
1/ Less than 1/2 unit.

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TABLE 5
U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Cadmium metal: 2/				
Austria	212	$9,370	--	--
Belgium	157,000	6,040,000	18,100	$75,000
Brazil	--	--	500	12,400
Canada	10,100	100,000	2,920	20,800
Chile	1,720	7,940	--	--
China	320,000	223,000	7,060	18,400
France	34,300	55,600	52,200	121,000
Germany	20	15,900	225	32,300
Hong Kong	474,000	369,000	--	--
India	--	--	18,000	25,400
Ireland	140	98,800	--	--
Israel	--	--	215	34,100
Italy	--	--	5,620	13,600
Japan	46,800	177,000	18	10,600
Korea, Republic of	3,440	29,600	33,400	297,000
Mexico	135	3,130	2,070	42,600
Netherlands	--	--	17,900	43,000
Norway	4,070	35,400	--	--
Singapore	--	--	1,500	12,700
Sweden	--	--	1,790	126,000
Taiwan	--	--	47	19,000
United Kingdom	15	4,210	1,380	21,900
Uzbekistan	--	--	31,800	14,100
Other	--	--	6,070	88,800
Total	1,050,000	7,160,000	201,000	1,030,000
Cadmium sulfide: (gross weight)				
Australia	49,300	36,800	17,800	6,680
Belgium	--	--	6,330	3,290
Canada	299,000	158,000	659,000	349,000
Colombia	20,400	5,650	45,600	23,700
Japan	126,000	67,600	--	--
Korea, Republic of	--	--	10,200	5,310
New Zealand	4,050	11,700	--	--
Other	7,570	3,940	57,400	11,500
Total	506,000	283,000	797,000	399,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes exports of cadmium in alloys, dross, flue dust, residues, and scrap.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Cadmium metal:				
Algeria	--	--	2,000	$8,380
Argentina	18,000	$39,600	--	--
Australia	5,000	19,700	48,000	93,500
Belgium	31,600	198,000	37,600	302,000
Canada	466,000	1,670,000	451,000	1,260,000
China	28,500	32,400	5,220	14,800
Finland	--	--	3,000	9,260
France 2/	38,800	90,000	3,540	29,600
Germany	61,900	205,000	50,700	110,000
Japan	2,480	32,200	492	62,600
Mexico	41,100	124,000	96,800	234,000
Netherlands	--	--	143,000	268,000
Norway	39,100	96,800	--	--
Peru	36,000	111,000	1,390	1,600
Russia	95	3,060	1	1,900
Switzerland	79,100	90,900	--	--
United Kingdom	--	--	15	3,430
Total	848,000	2,710,000	843,000	2,400,000
Cadmium sulfide: (gross weight)				
Austria	1,000	14,600	--	--
Belgium	4,580	61,000	455	1,300
Brazil	--	--	1,600	20,100
India	34,400	18,500	--	--
Japan	13,300	76,600	455	37,300
Russia	75	5,850	12	2,360
United Kingdom	4,210	49,700	11,100	94,900
Total	57,600	226,000	13,600	156,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ The 1995 data for France includes 31,000 kilograms of metal removed from bonded warehouses. The stored metal was valued at $27,700.

Source: Bureau of the Census.

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TABLE 7
CADMIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria	56	65	59 r/	59 r/	59
Argentina e/	37 3/	34	35	35	35
Australia	1,001	951	910	838 r/	682 3/
Belgium	1,549 r/	1,573	1,556	1,710	1,580
Brazil e/	200	200	300 r/	300 r/	300
Bulgaria	194	265	286	250 e/	250
Canada	1,963	1,944	2,173	2,349 r/	2,540
China e/	1,150	1,160	1,280 r/	1,200	1,300
Finland 4/	590	785	548 r/	539 r/	648 3/
France	252	137	6	-- e/	--
Germany	961	1,056	1,145	1,150 e/	1,150
India	313	255	216	254 r/	264 3/
Italy	742	517	475	308	296 3/
Japan	2,986	2,832	2,629	2,652	2,343 3/
Kazakstan	1,000 e/	1,000 e/	995	1,209 r/	1,200
Korea, North e/	100	100	100	100	100
Korea, Republic of e/	750	815	800	750	700
Macedonia e/	(5/)	(5/)	(5/)	(5/)	(5/)
Mexico 6/	602	797	646	689	675
Namibia	33	13	19	15	13
Netherlands	594	526	387 r/	300 e/	300
Norway	247	213	288	317 r/	274 3/
Peru	399 r/	472 r/	507 r/	510 r/ e/	510
Poland	132	149	61	-- r/	--
Romania e/	10	10	4 3/	5	5
Russia e/	800	700	500	500	550
Serbia and Montenegro	8	6	--	11	10
South Africa e/ 7/	60 3/	64	63	58 r/	63
Spain	361	329 r/	387	397 r/	307 3/
Thailand	635	449	643 r/	500 e/	600
Turkey	23	31	22 e/	23 r/ e/	20
Ukraine	5	7 e/	10	15 e/	15
United Kingdom 8/	383	458	469	549	541
United States 8/	1,620	1,090	1,010	1,270	1,530 p/ 3/
Zaire	84	12	1 e/	-- e/	--
Total	19,800 r/	19,000 r/	18,500 r/	18,900 r/	18,900

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.

2/ This table gives unwrought production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by a footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, Ware, the United Kingdom) and from Metal Statistics (published jointly by Metallgesellschaft AG, of Frankfurt, am Main, Germany, and World Bureau of Metal Statistics). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. This table includes data available through May 13, 1997.

3/ Reported figure.

4/ Excludes secondary production from recycled nickel-cadmium batteries.

5/ Less than 1/2 unit.

6/ Excludes significant production of both cadmium oxide and cadmium contained in exported concentrates.

7/ Cadmium content of cadmium cake.

8/ Includes secondary.

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CEMENT

By Hendrik G. van Oss

Cement is a critical component and economic indicator of the construction industry because it is the binding agent in concrete and mortars. Total U.S. production of portland and masonry cement in 1996 increased by 3.1% to 79.3 million tons,[1] of which 96% was portland cement (see tables 1-3). This record performance reflected near practical capacity output levels of clinker (see table 4) and cement (grinding) facilities. The United States continued to be the world's third largest cement producer (second in terms of high-quality cement); total world output remained in the range of 1.4 billion to 1.5 billion tons.

Apparent U.S. consumption of cement increased by about 5% in 1996 to 90.4 million tons, with the excess demand being met by increased imports and the drawing down of stockpiles. Cement exports also increased but remained a small component of total U.S. cement commerce. Cement prices were higher during the year, and the total ex-plant value reported for shipments from mills and import terminals to final customers increased by about 13% to $6.0 billion. The comparable value for all shipments to final customers, including those from other distribution terminals, is estimated to be $6.6 billion. By using typical cement-in-concrete mixing ratios, the value (delivered) of concrete in the United States in 1996 was estimated to be at least $26 billion.

In this report, cement production refers to finished portland and masonry cements (only) and thus represents the output both of integrated facilities (producing clinker and cement), and dedicated clinker-grinding plants. Hydraulic cements, which are those that will set and harden under water, are overwhelmingly the dominant type of cement manufactured in the United States and worldwide. Portland and masonry cements are the most common forms of hydraulic cements. Other hydraulic varieties, such as pure pozzolan and aluminous cements, cumulatively make up only a tiny fraction of the U.S. cement market and are not covered in this report.

The term "portland cement" properly refers to an interground mixture of portland cement clinker and 3% to 5% gypsum. The clinker comprises mostly calcium silicates and is made by controlled, high-temperature burning of a measured blend of calcareous rocks (usually limestone) with lesser quantities of silicious, aluminous, and ferriferous materials as needed. The blend is adjusted according to the chemical composition of the raw materials and the type of portland cement desired. In the United States, five basic types (Types I through V) of portland cement are recognized, denoting such properties as high sulfate resistance and high early strength. Elsewhere in the world, other designations may be used for similar portland cements. Portland cement is almost always gray, but if care is taken to burn only iron-free raw materials, then a more valuable version, white cement, can be obtained.

Portland cement can be interground with pozzolans to produce a variety of so-called blended cements. Blended cements have similar properties to (true) portland cements and, in common with standard U.S. industry practice, this report includes blended cements within the portland designation. Pozzolans are siliceous materials, such as certain rocks (mainly tuffs) and industrial byproducts (e.g., granulated blast furnace slag, fly ash, silica fume), that exhibit hydraulic cementitious properties when finely ground and interacted with free lime. Blended cements commonly are a major component of cement consumption overseas, particularly in Europe and Asia. As yet, reported U.S. consumption of pozzolans is very small, although the data are incomplete. The largest consumer is the concrete industry, but data for this industry are crude and do not differentiate consumption of pozzolans from similar material used as aggregates. Concrete is a controlled mixture of cement, fine and coarse aggregates, and water that, through complex cement hydration reactions, hardens into a rocklike mass of specifiable properties. The concrete industry uses pozzolans as concrete admixtures. In terms of the resulting cement paste, the distinction between adding pozzolans to the concrete mix or having them introduced to the concrete within a blended cement would appear to be more semantic than real.

The term "masonry cement" is used broadly in this report and includes portland lime and plastic cements. It is the cementing agent in mortar (a mixture of cement, fine aggregate, and water) that is used to bind together building blocks, such as bricks and stones. Masonry cements can be made either from portland cement or directly from clinker; manufacture involves incorporating a high percentage (e.g., 50%) of admixtures—commonly ground limestone or lime. This need not require a high degree of sophistication; in particular, portland-lime cements commonly are mixed at the construction sites, using purchased portland cement and lime. Accordingly, the data in this report, which are for masonry cement produced and sold by cement manufacturers only, underreport the true production and consumption of this material, particularly for some regions of the country.

The bulk of this report, particularly tables 1 through 7, and 10 through 15, incorporates data compiled from U.S. Geological Survey (USGS)[2] annual surveys of individual cement and

[1]All tons are metric in this report unless otherwise stated.

[2]Data prior to 1995 were collected by the former U.S. Bureau of Mines.

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clinker manufacturing plants and importers. In 1996, responses were received from 128 of the 134 facilities canvassed, including all but 1 producer; these facilities accounted for more than 99% of total U.S. cement production and shipments. In 1995, responses were received from 124 of the 130 facilities canvassed, recording 99% of production and shipments. Estimates were incorporated for the nonrespondents on the basis of monthly shipments data and/or past annual data. Tables 8 and 9, in contrast, are based on monthly shipments surveys of the cement-producing companies and importers, and for these, the response rate was 100% for both years. The several thousand U.S. concrete producers were not surveyed and, thus, the true production and consumption of pozzolans, and hence of "blended cement," are under represented.

For cases where annual questionnaires were returned incompletely filled out, followup inquiries were made, after which estimates were made and incorporated for any remaining missing data. Estimates for most information categories constituted only very small percentages of the aggregated totals and, thus, the introduced estimation errors are considered to be insignificant. Two important exceptions are the value data (tables 1 and 11-13), where a significant number of companies routinely withhold the information, and the data for portland cement shipments by customer type (table 14), where the cement producers readily admit to having incomplete knowledge.

As in previous years, there is a tonnage discrepancy between the annual shipments totals in tables 1-7 and 10-15 and the larger (monthly based) totals shown in tables 8 and 9. As a measure of cement consumption, the data in tables 8 and 9 are preferred because they are more complete; this will be discussed in more detail in the Consumption of Cement section. Integration of the data from tables 8 and 9 data with those from the other tables has not been done to avoid creating additional internal inconsistencies.

Tables 16 through 21 show nonproprietary trade data from the Bureau of the Census in lieu of the proprietary data collected through the USGS questionnaires. World production data shown in table 22 were derived by USGS country specialists from a variety of sources.

Some data are presented for State groupings or districts—generally corresponding to Census Districts or subsets thereof—where required to protect proprietary individual State data. Certain major cement-producing States have been subdivided along county lines to provide additional market information.[3]

[3]State subdivisions are as follows:

California, northern.—Counties north of San Luis Obispo and Kern Counties and west of Inyo and Mono Counties.

California, southern.—Inyo, Kern, Mono, San Luis Obispo, and all counties further south.

Chicago, metropolitan.—Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties in Illinois.

Illinois.—All other counties in the State.

New York, eastern.—All counties east of Broome, Chenango, Lewis, Madison, Oneida, and St. Lawrence Counties, but excluding counties within Metropolitan New York.

New York, western.—Broome, Chenango, Lewis, Madison, Oneida, and St. Lawrence Counties, and all those further west.

New York, metropolitan.—The five counties of New York City (Bronx, Kings, New York, Queens, and Richmond) plus Nassau, Rockland, Suffolk, and Westchester Counties.

Pennsylvania, eastern.—All counties east of Centre, Clinton, Franklin, Huntingdon, and Potter Counties.

Pennsylvania, western.—Centre, Clinton, Franklin, Huntingdon, and Potter Counties, and all those further west.

Texas, northern.—All counties north of Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, and Williamson Counties.

Texas, southern.—The named counties above and all those further south.

Within the U.S. cement industry, very few significant changes were reported in plant or company ownership during the year. In June, Scancem Industries Inc., of Norway, sold Continental Cement Co.'s Hannibal, MO, plant, plus distribution terminals in St. Louis, Chicago, and Bettendorf, IA, to a group of private investors, mostly from the St. Louis, MO, area; the Chicago terminal was subsequently sold to Holnam, Inc. Scancem retained ownership of Continental Cement Co. of Florida, Inc., which operates two Florida import terminals (International Cement Review, 1996a). Also in June, Holnam purchased Koch Minerals Co., which has granulated blast furnace slag (pozzolan) grinding facilities at Weirton, WV, and Chicago, IL (Rock Products, 1996a). Essroc Corp. announced the acquisition of distribution terminals at Wilder, KY, and Pittsburgh, PA, from Lafarge Corp (Essroc, 1996). Southdown, Inc., announced the purchase of Mitsubishi Cement Corp.'s cement distribution terminal in Phoenix, AZ (Southdown, 1996).

Legislation and Government Programs

Economic Issues.—Federal and State annual proposals and appropriations for public sector construction are ever of concern to the cement industry. Similarly, the industry monitors Government policies that influence the cost of money and other aspects of the general economic climate because these affect private sector construction projects. Because of high transportation costs, cement markets tend to be fairly local. Competition within markets served by more than one cement company can be keen, but similarities of production methods and costs have constrained cement sales price variations among companies. This has led to periodic Government antitrust investigations of the industry, to date without findings against the cement companies. One such investigation was concluded in 1995; none was reported in 1996.

Probably the most significant Government economic actions of recent interest to the cement industry have been regarding trade and stem from the 1980's when various factors led to a flood of cheap cement imports coming onto the U.S. cement market. Subsequent determinations of cement dumping by Japanese, Mexican, and Venezuelan cement companies led to the imposition of antidumping tariffs on imports from Japan and

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Mexico and to a voluntary restraint agreement with Venezuela. The tariffs have dramatically reduced imports of Japanese cement and clinker into the United States, from 2.1 million tons in 1990 to less than 500 tons in 1996. Anticipation and eventual imposition of tariffs on Mexican imports similarly led to a decline from a peak of 4.5 million tons in 1988 to 0.6 million tons in 1994. The tariffs were under appeal by the main Mexican company involved, and in the meantime, imports from Mexico began growing, totaling 0.85 million tons in 1995 and almost 1.3 million tons in 1996. Administrative reviews of the tariffs conducted by the U.S. Department of Commerce (DOC) on a periodic (12 months beginning August 1) basis for the years 1990 through 1995 have so far confirmed the tariff dumping margins. The latest reviews, covering the fourth and fifth periods (ending September 1995), were released by the DOC in April 1997 (Southern Tier Cement Committee, 1997).

Environmental Issues.—Cement production involves both mining and manufacturing components. About 120 million to 125 million tons per year of nonfuel raw materials are mined, generally from quarries. Environmental issues impacting this activity are common to most surface mines and include problems with dust, increased sediment loads to local streams, chemical changes to local water supplies, and so forth. Of far greater concern are the environmental impacts of the manufacturing process, most of which stem from the manufacture of clinker. Clinker kilns burn large quantities of fossil and/or other organic fuels to thermochemically break down (calcine) calcareous rocks and to instigate other clinker-forming chemical reactions.

In the growing debate over climatic change, the impact of so-called greenhouse gases on atmospheric warming is a major issue. The most common greenhouse gas is carbon dioxide (CO_2), and in the clinker kiln, fuel combustion and carbonate calcination evolve large quantities of this gas. The precise determination of the CO_2 emissions of the U.S. cement industry is difficult because compilations of chemical analyses for the specific types and quantities of raw materials and fuels actually consumed are lacking. Instead, estimates are made separately for calcination and fuel combustion. For CO_2 from calcination, two estimation methods are in common use. The first assigns average carbonate (CO_3^{-2}) contents to the carbonate rock types (tonnages) consumed (see table 5). The main problem with this method is that the carbonate content of limestones and other carbonate rocks vary widely; seldom is a pure calcium carbonate limestone used to make cement. A lesser problem is the small carbonate component of other rocks consumed—particularly shales—that tends to be ignored. The second method uses clinker production data and typical calcium (oxide) analyses of clinker to back-calculate the (calcium) carbonate component of the kiln feed. A problem with this method is that the calcium content of clinker also varies, although not widely as with carbonate rocks. A minor problem is introduced if one assumes, for simplicity, that all the calcium in the clinker is derived from calcium carbonate; in fact, other components of the feed, such as calcium silicates, can contribute calcium. And both methods fail to account for a small component of carbonate escaping, uncalcined or incompletely calcined, as cement kiln dust (CKD). With the first method and the raw materials data in table 5, a rough estimate can be made of CO_2 emissions from calcination in 1996 amounting to about 40 million tons, or about 0.57 ton per ton of clinker. With the second method, assuming a CaO content of clinker of 64% and that all the CaO was derived from $CaCO_3$, the CO_2 emissions from calcination would amount to about 36 million tons (0.51 ton per ton of clinker).

Estimation of CO_2 emissions from the combustion of fuels generally involves assigning carbon contents to the fuels consumed either directly or after calculated conversion to a common fuel (e.g., tons of coal equivalent). The error in both methods is in the assignment of a carbon content to a specific fuel type, such as coal, when a range of carbon contents may be present. This error probably is not large for fossil fuels, but could be significant for waste fuels, given that all sorts of organic substances (generally unspecified), ranging from paper to paint thinners, may be burned as wastes. Another, probably minor, problem is that many carbonate rocks contain organic carbon (kerogen)—some to a significant degree—and this material behaves as a fuel in the kiln. Kerogen would reduce the consumption of exogenous fuels, but its emission of CO_2 is unquantified. The fuel consumption data in table 6 would yield an estimate of CO_2 emissions of about 34 million 35 million tons (0.48-0.50 ton per ton of clinker).

Combustion and calcination combined would, for 1996, yield total CO_2 emissions of about 70 million to 75 million tons. This estimate and its components are probably good to within 10%. The total emissions, as estimated, are equivalent to about 1 ton of CO_2 per ton of clinker produced. The ratio would not change significantly on a cement-produced basis, assuming the cement is "straight" portland (clinker plus 5% gypsum). It would not hold, however, for blended cements, masonry cements, or any cement made by grinding imported clinker (for which the CO_2 emissions would be credited to the clinker source country). The above estimates are in close accord with those presented elsewhere; for example, Cahn and others (1997).

The above estimates do not include the CO_2 equivalent of the electricity consumed by the cement industry. Such emissions are commonly credited to the power industry. For a given plant or region, an estimate, ideally, would require knowledge of the percentage of the electricity sourced from thermal power plants and from what fuels therein. A simple estimate for the U.S. cement industry overall can be made by assuming an average "mix" of power-generation sources. According to 1995 data from the Energy Information Administration (1996), the U.S. industrial sector electricity consumption-to-CO_2 ratio was about 1,700 kilowatt-hours per ton of CO_2. Applied to the 1996 electricity consumption of the cement industry (see table 7), this would yield a CO_2 equivalent of about 7 million tons.

The concern of the cement industry with CO_2 emissions stems mainly from worries that the Government will seek to reduce emissions through the imposition of carbon taxes or emissions quotas. For administrative reasons, carbon taxes would most likely be imposed on the fuels consumed rather than on the emissions themselves. The fear is that the carbon taxes,

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especially if high, would significantly raise clinker production costs and would, thus, reduce the price competitiveness of domestic cement against (presumed) cheaper imports. The imports would be cheaper because so-called developing countries, including Mexico, are expected to be exempted, at least for a time, from carbon emissions limits and could, thus, produce cement more cheaply. Many of these same developing countries also have very large and efficient modern plants.

In February, the U.S. Department of Energy (DOE) initiated a study into the economic impacts of carbon taxes on six industries, including cement. The completed study, summarized in Nisbet (1996), noted that energy currently accounts for 30% to 40% of current production costs, that affordable technological options to improve energy efficiencies of existing plants are limited, and that the unit CO_2 emissions from calcination cannot be reduced. In the study, carbon taxes were imposed under two incremental (year 2005 and 2010) price scenarios, wherein the initial tax (2005) doubled in 2010. The cheaper scenario imposed a tax in 2005 of 8.4 mils ($0.0084) per kilowatt-hour of electricity, $40.67 to $44.10 per ton of oil equivalent on fuel oil, $28.77 per ton of oil equivalent of natural gas, and $35.45 per ton of coal. The more-expensive scenario was approximately 50% higher and was projected to increase total energy costs by an average of 151% in 2010. The cost increases would cause domestic cement to become increasingly uncompetitive with foreign cement (sourced from nontax countries), with the result that the industry could lose about 15 million to 24 million tons of production capacity through plant closures, and imports would increase by as much as 100% or more to compensate. However, the study was constrained by boundary conditions set by DOE and, accordingly, did not fully account for the possibility of imposition of protective tariffs, the likelihood that developing countries ultimately would not be excluded from carbon taxes, or that certain parts of the country would remain insulated from imports because of high transportation costs (which also would increase), or the possibility that there would be a large increase in the consumption of nonclinker (i.e., pozzolan) extenders in cement manufacture. Given its widespread use in Europe and Asia, pozzolan (blended) cement consumption is likely to grow in the United States even without carbon taxes, although the market is constrained, to some degree, by cement specifications in existing construction codes.

Another major waste product of clinker manufacturing is CKD, made up of particles of clinker, incompletely reacted raw materials and solid fuels, and material eroded from the kiln's refractory brick lining. Almost all CKD is captured by either electrostatic precipitation or baghouse filtration, either for reuse as kiln feed or as a soil conditioner for farms, or for storage in a landfill. Nevertheless, worries remain regarding unacceptable levels in some CKD of hazardous trace-element or organic contaminants, such as chromium compounds from refractory bricks, and nickel and vanadium from fossil fuels. Objections have been raised by environmental groups and commercial waste-incineration companies to perceived risks of contaminant emissions arising from the increasing use of waste fuels by the cement industry.

Under amendments to the Resource Conservation and Recovery Act (RCRA) in 1980, the U.S. Environmental Protection Agency (EPA) was instructed to study so-called Bevill (amendment) wastes, including CKD, to see if such were to be regulated under the hazardous waste provisions of RCRA. The EPA completed its Report to Congress on CKD late in 1993; in this, CKD was described as posing little environmental or health risk, but some ground-water contamination problems owing to CKD mismanagement were identified (U.S. Environmental Protection Agency, 1993 a,b). The EPA issued an associated regulatory determination in early 1995 that reaffirmed the risk conclusions of the 1993 Report, and proposed, under the authority of RCRA Subtitle C (hazardous wastes), drafting in consultation with interested stakeholders a tailored set of management standards for CKD (U.S. Environmental Protection Agency, 1995). Importantly, the 1995 determination ruled that the standards need not be the stringent ones in Subtitle C; that is, CKD was not ruled to be a hazardous waste. In March 1995, the cement industry, responding to a perceived lack of rigor in the determinations language, presented to the EPA a so-called enforceable agreement that laid out standards for CKD management (American Portland Cement Alliance, 1995). The EPA reviewed the industry proposal but, in November 1995, professed itself uncertain of its authority under RCRA to sign such an agreement (American Portland Cement Alliance, oral commun., 1996). Instead, the EPA began a regulatory development program in April 1996, with a target date for release of a proposed rule in early 1998 (U.S. Environmental Protection Agency, 1996).

Increasingly stringent Government restrictions on fuel-derived emissions of so-called NO_x and SO_x, dioxins and furans, and other contaminants, are of concern to the industry, particularly to the degree that changing emission limits necessitates changes in testing procedures, equipment, and operating practices. These limits also affect the ability of plants to utilize waste fuels cheaply. The Government was moving towards regulating kiln emissions within the regulatory Maximum Achievable Control Technology (MACT) framework and issued an extensive document setting out proposed MACT standards in April 1996. After receiving complaints from the industry that the original review period was too short, the EPA agreed, in December, to an extension, and reevaluated standards are expected to be released late in 1997. Under a MACT framework, the standards adopted for each contaminant are the average emissions levels of the least polluting plants; current proposals involve the least polluting 12% of the plants.

Production

Cement was produced in 1996 in 37 States and in Puerto Rico by 43 companies (other totals are possible depending on ownership splitouts), including 1 that was State owned. All but 7 of the 118 plants that were in operation were integrated facilities producing both clinker and cement. Production and related data are shown in tables 2 through 4. About 65% of

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U.S. cement production and capacity was foreign-owned.

Several cement companies were upgrading their plants to reduce operating costs and/or to increase capacity. Some of the projects announced during the year were major. Ash Grove Cement Co. completed a 0.15-million-ton-per-year capacity expansion project at the Leamington, UT, plant at midyear (Grover, 1997). Blue Circle America Inc. announced that it would start work in May to expand capacity at its Harleyville, SC, plant by more than 0.3 million tons per year; the work was expected to be completed by yearend 1997 (Portland Cement Association, 1996a). Holnam Inc. was converting its Devils Slide, UT, plant to dry process technology; the conversion was expected to be completed in late 1997 (International Cement Review, 1996b). Lafarge Corp. was planning to upgrade the kiln line at the Sugar Creek, MO, plant (Rock Products, 1996b). Lehigh Portland Cement Co announced that it was planning a modernization and 50% expansion (to 1.36 millio tons per year) program at its Union Bridge, MD, plant (Portland Cement Association, 1995); a tire-burning system for the kiln was installed as part of this project (U.S. Geological Survey, 1996a). Mountain Cement Co. brought a second dry kiln on line in January 1996 (U.S. Geological Survey, 1996b). North Texas Cement Co. completed construction of a large cement import terminal at Houston, TX, and received its first shipment in December (Wood and Olaveson, 1997). Rinker Materials Corp. announced that it would convert its Miami, FL, plant to dry process technology, thereby increasing capacity to 1 million tons per year (International Cement Review, 1996c); the work was due to be completed in 1999. Roanoke Cement Co. installed a single-string preheater/precalciner on its No. 5 kiln line (U.S. Geological Survey, 1996c). Southdown Inc. was expanding capacity at its Fairborn, OH, plant by 0.1 million tons per year and at Victorville, CA, by 0.3 million tons (Portland Cement Association, 1996c); a new finish mill was completed at Fairborn during the year (U.S. Geological Survey, 1996d).

The only permanent closure during the year was at Hawaiian Cement, which shut its kiln down at the end of August. The facility continued to operate as a grinding plant for imported clinker (Hawaiian Cement, oral commun., 1996).

Portland Cement.—In the United States and Puerto Rico, portland cement was manufactured at 118 plants, including 7 dedicated clinker-grinding facilities. The regional distribution of these plants, cement production and capacities, and yearend cement stockpiles are given in table 2.

Portland cement production rose by 3.4% in 1996 to about 75.8 million tons, a new record. As shown in table 2, increases were noted in all but a few States. The top five portland cement producer States continued to be, in descending order, California, Texas, Pennsylvania, Michigan, and Missouri. Nationwide, calculated cement (grinding) capacity utilization levels were at very high levels—almost 84% for the country. This statistic, however, is misleading in that it compares only the portland cement output with the reported grinding capacity. In reality, the masonry cement tonnage (table 3) should be incorporated, which would increase the overall grinding capacity utilization for the country to almost 88%. Given the fact that the reported capacities exclude downtime for unexpected maintenance, the utilization levels shown are likely very close to practical limits. Whether the 1995-96 changes in capacity utilization or in the capacities themselves are statistically significant for all regions remains unclear. Although a number of plants were involved with capacity improvement projects to one degree or another, some of the changes shown could simply reflect a difference in reporting personnel or in their data rounding from one year to the next.

Yearend portland cement stockpiles were down 0.4 million tons compared with those in 1995, but remained almost 0.7 million tons higher than those at yearend 1994. Although a reduction in 1996 stockpiles is in line with high levels of demand for cement, an analysis of the contribution of cement stockpiles to true consumption is precluded because of the absence of data on stocks of clinker, the intermediate product. As noted in the "Clinker" section, clinker output was inadequate to account for the portland cement production.

Data are not collected on the production of portland cement, by type, but production was probably proportional to the reported shipments, by type, shown in table 15. As in previous years, portland cement Types I and II presumably accounted for about 90% of total output.

Cement producers in the United States ranged from companies having a single plant of less than 0.5% of total U.S. capacity to large multiplant corporations. The largest of these had 13% of total U.S. cement production capacity. The top 10 companies in 1996, combined, accounted for 59.4% and 59.9% of total U.S. portland cement production and capacity, respectively. Their combined grinding capacity utilization averaged 83%. The top 10 companies were, in descending order of production, Holnam, Inc.; Lafarge Corp.; Southdown, Inc.; Ash Grove Cement Co.; Blue Circle Inc.; Essroc Materials, Inc.; Lone Star Industries, Inc.; California Portland Cement Co.; Medusa Corp.; and Lehigh Portland Cement Co.

Masonry Cement.—Reported production of masonry cement, as shown in table 3, declined modestly in 1996 to about 3.5 million tons (about 4% of total U.S. cement output). This was in contrast to increased demand, as evidenced by the shipments data in tables 8 and 12. At least some of the excess demand appears to have been met by drawing down masonry stockpiles; imports, however, may not account for the remainder. The amount of masonry shipments reported as of foreign origin (imports) in table 8 was substantially unchanged in 1996, and the trade data in tables 17 through 21 do not split out this cement type. Masonry cement continued to be produced by 32 companies at 84 plants, all but 1 of which also produced portland cement. Although not shown in table 3, of the masonry cement produced, 89% was made directly from clinker (vs. from portland cement) in 1996 and 93% was so derived in 1995.

Clinker.—Table 4 provides district-level information on clinker production and capacity. Including the facilities in Puerto Rico, clinker was produced by 111 integrated cement plants, operating 207 kilns. Almost two-thirds of the kilns used dry-process technology. Clinker production increased in 1996 by

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0.5% to about 70.4 million tons, and calculated capacity utilization increased slightly to almost 95%. After excluding the clinker needed to make masonry cement (not reported, but estimated to be about 2.1 million tons), the remaining clinker (about 68.3 million tons) would be adequate to account for about 71.9 million tons of portland cement—about 3.9 million tons less than that actually produced. The clinker deficit (estimated to be about 3.7 million tons) was only partially compensated for by clinker imports [2.1 million tons (table 5) or 2.5 million tons (table 21)], leaving a 0.6 million to 1.6 million ton deficit that implies a significant drawdown of clinker stockpiles during the year. Although quantitative data were lacking, a number of cement companies orally reported a decline in their yearend clinker stockpiles. Ultimately, evaluation of the significance of a yearend decline would be difficult, as clinker stockpiles commonly show significant seasonal variations, especially with respect to planned kiln maintenance periods.

The increase in the total U.S. capacity utilization rate could be artificial as it is dependent on reported daily and calculated annual capacities, both of which declined about 2% in 1996. The capacity declines were unexpected as the 1996 data include a small plant in Nevada that was not incorporated in the 1995 data, as well as a new dry kiln in Wyoming. Further, the 1996 capacity data include Hawaiian Cement, despite the fact that it permanently shut its kiln in August; its inclusion, however, does not significantly affect the U.S. declines shown. There were no permanent shutdowns in 1995 that could have decreased the 1996 capacity basis. Past surveys have revealed inconsistencies for some plants in the reporting of scheduled vs. unscheduled downtime; only the scheduled downtime influences the calculated annual capacities. Accordingly, the total capacity declines for 1996 may include a measure of reporting or definitional errors. Notwithstanding these problems, the data indicate that U.S. cement kilns clearly operated at essentially full practicable capacity, as in 1995. The average operational plant capacity was about 0.36 million tons, slightly below that reported in 1995 but subject to the uncertainties given above. As shown in table 6, (entirely) dry-process plants accounted for 71.5% of total clinker production; wet plants for 25.8%; and combination plants for the remainder.

The top five clinker-producing States continued to be, in descending order, California, Texas, Pennsylvania, Missouri, and Michigan. The top 5 companies had about 38% of total U.S. clinker production and capacity, and the top 10 companies had about 59% of both. The top 10 companies were, in declining order of clinker output, Holnam, Inc.; Lafarge Corp.; Southdown, Inc.; Ash Grove Cement Co.; Blue Circle Inc.; Lone Star Industries, Inc.; Essroc Materials, Inc.; Medusa Corp.; California Portland Cement Co.; and Lehigh Portland Cement Co.

Consumption of Raw Materials and Energy.—The nonfuel raw materials used to produce cement, most of which were consumed in clinker manufacturing, are shown in table 5. As normal, about 85% of the raw materials mix was limestone and other calcareous rocks. The small decline in limestone consumption appeared to have been balanced, in terms of CaO credits, by the large increase in the consumption of cement rock (impure limestone). The cement rock also would have added significant silica credits that, together with the higher consumption of clay, could have more than offset the reduced consumption of shale, sand, and sandstone. Similarly, any iron and aluminum deficits from reduced shale consumption appeared to have been more than offset by the cement rock and increased consumption of clay, iron ore, and similar materials.

The increase in gypsum consumption shown is almost exactly proportional to that in cement production. Likewise, the modest increase in slag consumption is proportional to that in blended (with slag) cement sales shown in Table 15, assuming that the sales mirror the production and that, as seems likely, the slag was all used as a cement extender. In contrast, the fly ash consumption shown in table 5 clearly exceeds that used in fly ash blended cements (per sales in table 15) and indicates that most of the fly ash was being used as kiln feed.

Consumption of fuels, by kiln process, is shown in table 6. The table differs from that in previous editions of this report in that coke and petroleum coke are now listed separately from coal. Overall, coal consumption increased modestly, although part of this increase was offset by a decline in petroleum coke use. The burning of waste tires and other solid waste fuels increased. Most of the solid fuel consumption increases were at dry-process plants. Fuel oil consumption increased 52%, especially by wet-process plants (up 121%). Liquid waste fuel consumption also increased, also mostly by wet plants. In contrast, natural gas consumption fell by about one-third at both types of plants, indicating that coal and oil were being substituted for gas, probably because of the more than 50% average unit price increase for gas during the year (Oil & Gas Journal, 1997a). Although not shown in table 6, estimates may be made of the energy content of the fuels consumed by using standard heat conversions. For the waste fuels (undifferentiated), however, the energy content assignment error may be significant. The analysis further assumes the same heat content for the same fuel type in both years. On this basis, it was estimated that wet kilns used about 4% less total energy in 1996 than in 1995 and that dry kilns showed no significant change. Given that clinker output by wet kilns fell by 1.5% in 1996, and output by dry kilns increased by 1.4%, the estimated reduction in energy consumption suggests that most of the kilns, especially the wet-process lines, showed improved fuel consumption efficiencies in 1996.

Table 7 shows electricity consumption by integrated cement plants, by kiln-process type. The table differs from previous versions in that the unit consumption is now calculated for total finished cement (including masonry) instead of just for portland; for 1995, this revision has caused the average consumption to drop by 4 kilowatt hours per ton. Electricity consumption at integrated plants is dominated by the raw meal and finished cement comminution circuits. In modern dry lines, significant amounts of electricity also are used to operate various fans and blowers in preheater and precalciner equipment. Thus, dry-process kiln lines—at least those equipped with preheaters and/or precalciners—consume more electricity than equivalent

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capacity wet-process lines. For 1996, unlike the fuel consumption decreases noted above, per-ton (cement) electricity consumption showed no change for wet-process lines and increased by 1% and 2% for the dry- and the combined-process lines, respectively. The average cement-to-clinker production tonnage ratio increased by 2.9% to 1.08. This suggests that the higher unit electricity consumption in 1996 reflects increased electricity use by the finished cement grinding circuits. Raw materials crushing, or the kiln lines, may also have used proportionately more electricity in 1996. Unfortunately, data to evaluate this are not available.

Consumption of Cement

Data for cement shipments to final customers are accepted as being a proxy for true consumption levels in the United States. In contrast, shipments by one cement producer to another, whether or not of the same company, are not counted until, ultimately, the cement is sold to a final customer. The determination of what is and is not a "final customer" is left to the reporting cement producer. "Final customer" is understood to include concrete manufacturers, building supply dealers, construction contractors, and the like. The designation ignores the possibility that a customer might put some cement into stockpiles extending beyond yearend (to be "consumed" the following year) or might resell cement to other users. There are no data on such storage or transfers, but they are believed to be small—probably no more than 5% of any 1-month's shipments—and would likely balance out over a period of months.

Cement shipments data and derivations therefrom are given in tables 8 through 15. These tables reflect two data-collection methodologies. Tables 8 and 9 contain the annualized shipments data that are collected monthly from the cement-producing companies and from the cement importers. The monthly surveys commonly are returned on a consolidated basis—one form representing a company's entire cement shipment activities. Importantly, these surveys capture the activities of a company's importation and distribution terminals. Tables 10 through 15, in contrast, are based on annual surveys sent to all of the cement-producing plants and certain independently-owned import terminals. The annual forms are not returned on a consolidated-operations basis. A plant may report the shipment (to final customers) activities of a distribution terminal only to the extent that activities of the terminal are known to the plant. If the terminal acts partly or totally independently of the reporting plant, then some of the shipments from the terminal may remain unreported to the USGS.

Not surprisingly over the years, differences in the totals from the two survey types have been significant. For example, table 8 (monthly surveys) shows portland cement shipments to final customers (excluding exports) of about 82.9 million tons in 1995 and 87.6 million tons in 1996. Table 11 (annual surveys) shows shipments of 75.0 million tons in 1995 and 81.5 million tons in 1996. Both surveys include cement made from imported clinker and imported cement shipped out by the reporting entity. The difference in shipments—7.9 million tons in 1995 and 6.1 million tons in 1996—most likely reflects the cement importing activities of terminals not captured in the annual surveys (e.g., table 11). Accordingly, the preferred consumption data are those based on the complete monthly data; that is, tables 8 and 9.

Comparison of tables 8 and 9 with tables 11 and 12 also reveal differences on a State or district level. Tables 11 and 12 show a mix of State and district data where needed to conceal proprietary data. The mix is necessary because the annual surveys collect data from producers, and the regions shown are the originating districts, not the destinations, of the shipments. Except for masonry cement shipments for a small number of States, this precaution is not necessary for the shipments by destination data in table 8. The distinction between "origins" and "destinations" of shipments also explains why State data in table 8 differ from individual State data (where shown) in table 11. For example, table 8 shows Alabama as being the destination (consumer) of 1.47 million tons of portland cement in 1996, but table 11 shows Alabama as being the origin of 4.14 million tons of portland sold to final customers. Clearly, Alabama cement producers sold material to final customers outside of Alabama. Table 8 shows North Texas as having consumed 4.37 million tons of portland cement in 1996, but table 11 shows North Texas plants as shipping only 3.56 million tons. Clearly, North Texas consumers brought in cement from outside the region.

Although the monthly-based data in tables 8 and 9 are the preferred consumption data, no attempt has been made to reconcile these data with the annual data on shipments by type of cement, by mode of transportation, or by value, or the like. To maintain internal consistency, the annual shipment totals (e.g., tables 11 and 12) are used wherever these other annual data are presented.

National Consumption.—Table 8 shows that overall U.S. portland cement consumption increased by 5.6% in 1996 to about 87.6 million tons. Of the total shipments, those representing imports decreased slightly, but the change is partly administrative. A change was made in the reporting methodology for shipments in 1996 wherein all cement ground from imported clinker was to now be credited as having originated in the United States. For 1995 and prior years, some companies had reported this cement as being of foreign origin. It was, however, impractical to adjust the pre-1996 data. Imports of finished cement (all years) were unaffected by the reporting change. Consumption reflected a largely countrywide increase in construction. According to Bureau of Census data quoted by the Portland Cement Association (1996b), total construction spending grew by 1.9% in 1996 to $495.8 billion (1992-basis dollars). Within this, the largest gains were seen in residential construction: single-family housing construction spending grew by 6.6% to $135.5 billion, and multiple-family housing grew by 10.2% to $17.3 billion. In 1995, this interest-rate-sensitive sector had declined in line with modest increases in mortgage rates. The mortgage rates continued to increase, although remaining at modest levels, until the fourth quarter of

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1996, when they declined somewhat. The residential construction increase in 1996 thus appears to reflect an overall stronger economy and pent-up demand. These factors also appeared to have helped private nonresidential construction, which grew by 3.0% to $123.4 billion. Public sector spending was, overall, stagnant at $123.9 billion. Within this, public building construction grew by 4.1% to $55.6 billion, but the important highway/street construction sector fell by 1.4% to $34.4 billion.

As shown in tables 8 and 9, most States and all regions showed consumption increases for the year, although there were some monthly regional declines (not shown) due to poor weather conditions. The largest growth regions were the Midwest and the West, notwithstanding the fact that the Mountain district within the West also had the majority of the (few) States nationwide that showed declines for the year. The declines were more than offset by strong increases in Arizona, Colorado, and Nevada, all of which were experiencing high population growth. Nevada also continued to see growth in consumption by the mining industry. For the country, the five largest portland-cement-consuming States continued to be, in declining order, Texas, California, Florida, Ohio, and Georgia. The South was again the largest cement-consuming region.

Reported masonry cement consumption increased by 6.7% overall, although, as noted in the definitions section of the introduction, the data likely underrepresent the true consumption of this type of cement. The increase largely reflects that in the residential construction sector.

Table 10 shows portland cement shipments to final customers in terms of transportation method. As in 1995, most shipments were directly from the plant to the customer and were mainly of bulk cement. Truck transport dominated deliveries to final customers, but not of deliveries from plant to distribution terminals.

Prices.—The price or value data shown in tables 11 through 13 represent ex-plant valuations by the mill of cement shipments to final customers. Although the plants are asked to provide annual portland cement shipment data, by tonnage and type (table 15), they are not asked for details concerning the value of the sales, by type, in recognition of some companies' misgivings about providing any value data at all. Instead, the values are queried only as totals for all shipments—one total for gray portland cement (all types), another for white portland cement, and another for masonry cement. Even with this accommodation, about one-fourth of the respondents did not provide value data for the 1996 survey, about the same as in previous years. In such cases, the values supplied by other plants in the same market area were averaged and applied; the number of plants so averaged varied regionally. The unit values shown are calculated averages for the whole year and do not reveal temporal variations. Further, the values represent the combined total or average of bulk and container (bag) shipments. In reality, the unit price difference between the two forms of shipments (bulk being cheaper) is significant. These and other variables preclude detailed error analysis of the results. The reader is cautioned that the value data are merely estimates, despite the fact that, to preserve a time series with previous editions of this report, they are presented unrounded. The data should be viewed solely as regional price indicators, suitable only for crude comparisons among districts and years. Although the data are thus not actual prices for specific type(s) of cement, the values shown for portland cement in tables 11 and 13 may be assumed to be dominated by the Types I and II varieties.

The ex-plant value of portland cement shipments to final domestic customers is shown in table 11. The total value rose almost by 14% in 1996 to about $5.7 billion, reflecting increased sales volume and, within the aforementioned data constraints, an ex-plant unit price (indicator) increase of almost 5%. If the average price shown is applied to the shipments data in table 8, then the total rises to almost $6.2 billion. Ignoring price-indicator changes of less than $0.50 per ton (which are almost certainly of no statistical significance), district unit price increases were seen in all except a few districts. The largest decreases (Maine-New York and Alaska-Hawaii-Oregon-Washington) appear to be, at least in part, aberrations reflecting incomplete reporting in one or both years. Average price (including freight) data for regional imports of hydraulic cement plus clinker (see table 18) suggest that some of the decreases shown (Oregon, Hawaii, Maine, New York, and possibly Florida) could partly reflect import price decreases. However, although far less detailed, the gray portland import data in table 19 suggest that the decreases seen in table 18 may be due more to clinker than to cement. Although not shown in the tables, the change in these districts in the consumption of expensive portland cements (such as white cement) was insufficient to account for the value decreases shown.

In table 12, masonry cement values show a total increase of more than 14% to almost $323 million and an average 6.0% price increase. In contrast to portland cement, if the average masonry unit value shown is applied to the consumption data in table 8, then the total value decreases to about $312 million. This decrease reflects the lower tonnage in table 8; a similar relation was seen for 1995 relative to 1994. A possible explanation for this tonnage difference, which is the reverse of that expected from the data-collection methodologies, is that the table 12 tonnages may include late-year shipments from plants that were destined for final customers, but that were not invoiced until the following year, or shipments that wound up in stockpiles at terminals. A summary of average cement ex-plant values, by major type, is given in table 13.

The only data for domestic delivered prices for cement are those for Type I portland (per short ton) and masonry cement (per 70-pound bag) published monthly by the journal *Engineering News Record*. The data represent a survey of customers (likely to be ready mixed concrete producers for portland cement and building supply depots for masonry) in 20 cities in the United States. The 20-city average delivered price in 1996 for Type I portland converts to $80.35 per metric ton, up by 6% from the 1995 price, with a range over the year of only $2.54 per ton. Prices showed a general increase from January to December ($81.32). The city data show a number of

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regional price differences, some of which differ significantly from those shown in table 11. The variations could reflect regional differences in shipping methods and costs. The prices for some cities covered, however, did not vary at all over the year, making their validity and that of the national average questionable. The 20-city average masonry cement price for the year was $4.47 per bag (literally converts to $140.78 per ton) and ranged only $0.11 per bag over the year.

Cement Customer Types.—Table 14 presents data on portland cement shipments to final customers broken out by customer type. Although presented in unrounded form, these data are less reliable than any of the other data collected in the annual survey, with the exception of the value data, as explained earlier. Unlike the value data, however, the main problem with the customer-type data is not a lack of survey responses, but the fact that the questionnaire asks for more details on customer types than many cement companies are able to provide. Even for companies tracking their customers' usages in detail, the assignment of cement sales tonnages to the 15 use(r) categories on the questionnaire can still be a problem. For example, a company may know that a certain ready-mixed concrete customer used X tons of cement (in ready-mixed concrete) for road paving contracts. The dilemma, then, is whether to register those tons under the ready-mixed category or the road paving category. Another example would be the "Government agencies" use category on the questionnaire—Government use could include ready-mixed concrete, or road paving, or other duplicative use(s). The "Other" category on the questionnaire, which is intended to mean "miscellaneous," is used by some cement plants use as a catch-all. Further, although generally listed as exact tonnages, some company responses calculate to simple (broad) percentages of the total shipments—the breakdown being the "best guess" of that cement plant. In a few instances, the apportioning appears to have been guided by past published breakdowns. Ultimately, then, the problem is partly interpretational: "type of customer" is not exactly the same thing as "type of use."

Notwithstanding these limitations, the data in table 14 clearly indicate that the dominant customer type for portland cement in 1996 continued to be ready-mixed concrete producers. As listed, cement for ready-mixed concrete (customers) accounted for about 60% of total cement shipments (61% in 1995). Of the total shipments listed under "Government and miscellaneous," however, 50% to 60% likely were used for ready-mixed concrete, which would have then accounted for about 70%. Similarly, the (footnoted) breakout of the "Contractors" category probably understates true consumption for road paving—some cement for this purpose no doubt resides under the "Government and miscellaneous" and the "Ready-mixed concrete" categories. In contrast, the data for concrete products manufacturers, buildings materials dealers, and oil well cement uses are probably fairly accurate. Overall, the relative usage breakdowns are very similar to those of 1995. The largest relative (tonnage) change was in "Oilwell, mining, waste," which increased by almost 24%. The category includes a 43% increase in cement purchases by oil-well drillers (the tonnage is slightly less than that shown for oil-well cement sales in table 15). The "oil well" increase is in accord with heightened drilling activity during the year, as evidenced by a much higher drill rig count (Oil & Gas Journal, 1997b) and the increased consumption of barite by the petroleum exploration industry (Searls, 1997). Although the cement customer types are shown in table 14 on a District basis, the data reflect the origins of the cement, not the locations of the customers, and are thus only an indirect regional indicator of portland cement usage.

Types of Portland Cement Consumed.—As shown in table 15, portland cement consumption in the United States remained dominated by general-use Types I and II. Within the broad use of the portland term, Types I through V accounted for more than 96% of total shipments. Of these main varieties, Type V cement, which is resistant to so-called sulfate attack, showed the largest relative increase during the year. Of the less common varieties, oil-well cement showed a large relative increase in shipments owing to an increase in drilling activity during the year, as discussed above. White cement (all varieties) showed a large relative increase in sales during the year, owing to a strong residential construction market but remained less than 1% of total U.S. cement consumption. After increasing significantly in 1995, blended cement consumption was surprisingly stagnant in 1996. An increase had been expected, given the common industry perception of a growing market for blended cements. Unfortunately, regional consumption data for blended cements are unavailable; market growth is perhaps present but geographically restricted. As noted above, the true level of "blended" cement consumption is unknown because concrete manufacturers can independently add pozzolans to their concrete mixes to yield, in effect, a blended product. Within the two blended cement categories in table 15, that which includes portland-slag cements can completely accommodate the blast furnace slag consumption noted in table 5. However, the second category, which includes portland-fly ash blends, cannot begin to accommodate the fly ash indicated in table 5. Thus, most of that fly ash must be consumed as kiln feed.

Foreign Trade

Trade data from the Bureau of the Census are shown in tables 16 through 21; tables have been added to the present report to show the splitout of imports of gray portland and white cements. As shown in table 16, total exports of hydraulic cement (all types) and clinker rose almost by 6% in tonnage and almost by 10% in value in 1996; nevertheless, these exports remained but a tiny fraction of total U.S. cement commerce. An estimate of the cement component of the exports can be calculated from those of portland and masonry cement in table 8; such exports amounted to 0.486 million tons in 1995 and 0.461 million tons in 1996. Assuming that exports of other forms of hydraulic cement were substantially nil, the table 8 (portland plus masonry cement) exports are equivalent to 64% and 57% of the total table 16 exports for 1995 and 1996, respectively. Accordingly, clinker (a cheaper product than cement) exports showed a decline in 1996, and thus, the higher overall export value in

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1996 must reflect higher cement prices. As in previous years, the bulk of the exports went to Canada.

Table 17 shows total imports of hydraulic cement and clinker for 1995 and 1996. Total imports increased by only 2% in 1996, compared with a 1995-over-1994 increase of almost 23%. On a monthly basis, imports in 1996 were below 1995-levels through November, although there was a surge from September onwards (U.S. Geological Survey, 1996e). Despite steadily rising monthly demand, high domestic cement production levels throughout 1996 and the ability to draw from stockpiles of cement and clinker, appear to have been the main constraints on imports during the year.

The cement component of imports (data in table 17 minus the clinker imports in table 21) was 11.6 million tons, up by 5.6% over that of 1995. The import component of total cement sales shown in table 8 amounts to 11.9 million tons—the higher figure in table 11 probably includes imported material sold from stockpiles. Gray portland cement imports increased by 6.3% in 1996 to 10.1 million tons. As shown in table 19, the landed value (including freight) of gray portland imports averaged $53.82 per ton, up by 3.2%, and substantially below the average value for U.S. sales shown in table 13. Canada continued to be the largest source of portland imports, which increased by 10.9% (tonnage). Imports from Mexico increased by 50.4% from the depressed levels of 1995, notwithstanding high antidumping tariffs (which were under appeal) imposed on imports from that country. White cement imports (see table 20) declined by 10.6% in 1996, although the value rose by 15.4% to $120.65 per ton—well below the domestic sales value indicated in table 13. The imports were equivalent to almost 58% of the white cement sales shown in table 15; imports were equivalent to 72% of white cement sales in 1995. The decline in the apparent import component of sales in 1996 could represent either an increase in domestic production of white cement or greater sourcing of cement from stockpiles during the year.

Clinker import tonnage fell by almost 11%, but increased by 15.5% in value to $48.40 per ton (table 21). Canada remained by far the largest source, although imports declined almost 9%.

World Review

World hydraulic cement production is shown in table 22. Informal, but credible, commentary on past editions of this table suggests the strong possibility that the production numbers reported by some countries may, in fact, include exports of clinker. The countries involved and the degree to which this may be true are not known, but the clinker export component could be significant for some countries. Such a regrettable reporting practice would necessarily lead to overcounting (estimated to be less than 5%) within the world totals because the entire production of some countries, and the partial production of many others, includes cement ground in-country from imported clinker. Given this uncertainty, (unrelated) revisions to past data, and the inclusion within the unrounded world totals of production estimates for a number of countries, the 2.8% increase for 1996 world cement output probably has no statistical significance.

Within the world cement output of about 1.4 billion tons, China remained, by far, the largest producer, with about one-third of the total. The remaining top 10 producers were, in descending order, Japan, the United States, India, the Republic of Korea, Germany, Thailand, Italy, Turkey, and Russia. Comparison of production levels among some countries can be misleading, however, unless they are made for output of similar-quality cements. For example, throughout the world, portland and related cements from clinkers manufactured in large rotary kilns are considered to be generally of high quality. Cements from clinker made in small vertical (shaft) kilns, in contrast, may be of lesser quality; unsuitable for modern highways, bridges, large dams, tall buildings, and the like, or for exports, but perhaps entirely adequate for local demand for small, single-family residences and similar buildings and other low-strength applications. Shaft kilns for cement have been replaced almost entirely by rotary kilns in the so-called developed world but remain common in a number of less-developed countries. Thus, according to recent reviews (e.g., Hargreaves, 1997; Rong and others, 1997), China's cement production would be better viewed as comprising about 50 million tons of high- or export-quality cement from a relatively small number of medium and large rotary kilns and about 440 million tons of cement of uncertain quality from several thousand small shaft kilns (many of which are being phased out).

Even a cursory review of the 1996 cement trade literature (e.g., *International Cement Review, Rock Products Cement Edition, World Cement*) reveals the fact that new cement plant projects abound in most parts of the developing world; by comparison, the cement industries many of the major western industrial countries seem almost stagnant. The new cement plants being constructed or planned in the developing countries commonly are large and state of the art. Many are owned by the same giant European cement companies that dominate production in Europe and North America; likewise, most of the plant equipment and engineering services were being supplied by European and North American manufacturers.

As in 1995, much of the growth in the international cement market and in production in 1996 was in Asia, particularly in Southeast Asia and China. China is experiencing rapid growth in infrastructural spending and is seeking to replace its multitude of small, village-scale cement plants with large, modern facilities serving larger regions. In some countries in Asia, particularly Indonesia, planned capacity increases appear to be well in excess of anticipated domestic demand and would argue for growth in cement and/or clinker exports. A number of new projects were underway in various countries of the Middle East, and some of these, too, appeared to be geared towards export opportunities. Although activity in Western Europe was largely confined to modest upgrades of existing plants, major upgrade investments (by Western European companies) were underway at recently privatized existing plants in Eastern Europe. New plants and/or plant upgrades were underway in a number of Latin American countries, particularly Brazil. Africa, in contrast, had fewer major projects underway, most of which

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were in Egypt.

Outlook

World cement demand and production is anticipated to grow steadily at about 2% per year during the next decade, with the developing world generating and absorbing much of the increase. This is in line with predictions of continued high rates of general economic growth but assumes continued availability of venture capital for such high-cost projects as new cement plants.

Data through the third quarter of 1997 yield a projection of U.S. cement consumption for the year 4-5% higher than 1996 levels—somewhat higher than had been expected. Consumption in the medium term was expected to grow more modestly. Cement production in 1997 is predicted to increase only by about 2%, largely owing to the majority of plants already being operated at full practical capacity. Although several million tons of additional domestic production capacity was expected to be available by the year 2000, imports were anticipated to continue to play a major role in the U.S. cement market, at least in the short term. Indeed, cumulative imports, as of midyear 1997, were more than 25% higher than for the same period in 1996. As always, market growth could be constrained by higher interest rates, which especially affect the residential construction market. And public sector construction funding levels will continue to be important.

An important constraint on future domestic cement production increases will be any imposition of restrictive environmental legislation, particularly that requiring a majority of plants to reduce emissions to match that of their larger and more-modern competitors, and to restrict the ability of the industry to cheaply use waste fuels. If restrictions or taxes on CO_2 emissions are imposed, then the U.S. industry would find itself at a competitive disadvantage to imports from countries exempted from similar restrictions or taxes; absent protective tariffs, some shutdowns of domestic capacity could take place. Environmental cost increases could partly be mitigated by increasing the utilization of nonclinker components of cement, such as pozzolan or inert extenders.

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TABLE 1
SALIENT CEMENT STATISTICS 1/ 2/

(Thousand metric tons unless otherwise specified)

	1992	1993	1994	1995	1996
United States: 3/					
Production 3/ 4/	69,585	73,807	77,948	76,906	79,266
Shipments from mills 3/ 5/	69,203	72,770 r/	79,087 r/	78,518 r/	84,955
Value 3/ 5/ thousands	$3,779,286	$4,174,819 r/	$4,844,869 r/	$5,329,187 r/	$6,044,944
Average value per ton 3/ 6/	$54.61	$55.65 r/	$61.26 r/	$67.87 r/	$71.15
Stocks at mills, 3/ Dec. 31	5,272	4,788	4,701 r/	5,886 r/	5,488
Exports 7/	746	625	633	759	803
Imports for consumption:					
Cement 8/	4,582	5,532	9,074 r/	10,969	11,565
Clinker	1,532	1,507	2,206 r/	2,789	2,401
Total	6,114 r/	7,040 r/	11,280 r/	13,758 r/	13,967
Consumption, apparent 9/	74,158 r/	79,198 r/	86,476 r/	85,931 r/	90,426
World: Production e/ 10/	1,123,143 r/	1,292,379 r/	1,372,427 r/	1,443,689 r/	1,484,564

e/ Estimated. r/ Revised.

1/ Portland and masonry cement only, unless otherwise indicated.

2/ Excludes Puerto Rico.

3/ Includes cement made from imported clinker.

4/ Shipments are to final customers. Includes imported cement. Data are based on annual survey of plants; may differ from tables 8 and 9, which are based on consolidated monthly shipments data from companies.

5/ Plant valuation (f.o.b.) of portland (all types, including white) and masonry cement shipments from mills to final customers. Although presented unrounded, the data contain estimates for some plants.

6/ Total plant valuation (f.o.b.) of cement shipments to final customers divided by total tonnage of same. Although presented unrounded, the data contain estimates for some plants.

7/ Hydraulic cement (all types) plus clinker.

8/ Hydraulic cement, all types.

9/ Production (including that from imported clinker) of hydraulic cement plus imports of cement minus exports of cement minus change in stocks.

10/ Total hydraulic cement. May incorporate clinker exports for some countries. Includes estimates for some countries.

TABLE 2
PORTLAND CEMENT PRODUCTION, CAPACITY, AND STOCKS IN THE UNITED STATES, BY DISTRICT 1/

(Thousand metric tons unless otherwise specified)

	1995 2/					1996 3/				
			Capacity 4/		Stocks 5/			Capacity 4/		Stocks 5/
District	Plants active	Production 6/	Finish grinding	Percent utilized	at mills, Dec. 31	Plants active	Production 6/	Finish grinding	Percent utilized	at mills, Dec. 31
Maine, New York	4	2,937	3,937	74.6	317	4	2,966	3,348	88.6	234
Pennsylvania, eastern	8	4,045	5,019	80.6	355	7	4,057	5,152	78.7	243
Pennsylvania, western	4	1,565	2,009	77.9	146	4	1,615	2,009	80.4	105
Illinois	4	2,559	3,379	75.7	210	4	2,619	2,871	91.2	149
Indiana	4	2,328	2,597	89.6	253	4	2,347	2,731	85.9	185
Michigan	5	5,399	6,999	77.1	336	5	5,387	6,999	77.0	295
Ohio	3	1,049	1,588	66.1	94	3	1,054	1,588	66.4	62
Iowa, Nebraska, South Dakota	5	3,724	5,576	66.8	364	5	3,931	5,489	71.6	322
Kansas	4	1,725	1,774	97.2	185	4	1,725	1,783	96.7	149
Missouri	5	4,362	5,059	86.2	395	5	4,531	5,150	88.0	410
Florida	6	3,166	4,382	72.3	195	6	3,445	4,667	73.8	280
Georgia, Virginia, West Virginia	5	2,426	3,700	65.6	243	5	2,473	3,700	66.8	219
Maryland	3	1,670	1,837	90.9	192	3	1,609	1,837	87.6	105
South Carolina	3	2,210	3,067	72.1	111	3	2,368	3,075	77.0	85
Alabama	5	4,091	4,755	86.0	261	5	4,326	4,804	90.0	271
Kentucky, Mississippi, Tennessee	4	2,107	2,474	85.2	216	4	2,216	2,474	89.6	187
Arkansas, Oklahoma	4	2,544	2,717	93.6	202	4	2,553	2,889	88.4	191
Texas, northern	6	3,807	4,512	84.4	229	6	3,906	4,712	82.9	270
Texas, southern	5 7/	4,285	4,717	90.8	227	5	4,332	4,726	91.7	218
Arizona, New Mexico	3	2,061	2,333	88.3	47	3	2,217	2,140	103.6	63
Colorado, Wyoming	4	1,851	2,377	77.9	90	4	2,031	2,377	85.4	125

See footnotes at end of table.

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TABLE 2
PORTLAND CEMENT PRODUCTION, CAPACITY, AND STOCKS IN THE UNITED STATES, BY DISTRICT 1/

(Thousand metric tons unless otherwise specified)

District	1995 2/ Plants active	Production 6/	Capacity 4/ Finish grinding	Capacity 4/ Percent utilized	Stocks 5/ at mills, Dec. 31	1996 3/ Plants active	Production 6/	Capacity 4/ Finish grinding	Capacity 4/ Percent utilized	Stocks 5/ at mills, Dec. 31
Idaho, Montana, Nevada, Utah	7 r/	2,206	2,445	90.2	155	7	2,216	2,696	82.2	209
Alaska, Hawaii	1	357	499	71.5	56	1	312	499	62.5	45
California, northern	3	2,554	2,867	89.1	107	3	2,610	2,880	90.6	125
California, southern	8	6,808	7,899	86.2	250	8	7,297	7,943	91.9	279
Oregon, Washington	3	1,467	1,796	81.7	124	4	1,655	1,960	84.4	133
Total or average 8/	116 r/	73,303	90,316	81.2	5,359	116	75,797	90,497	83.8	4,959
Puerto Rico	2	1,414	2,004	70.6	40	2	1,552	2,004	77.4	37

r/ Revised.

1/ Includes Puerto Rico.

2/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: California, Florida (2), Iowa, Michigan, Ohio, Pennsylvania, and Texas.

3/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: Florida (2) Michigan (2), Ohio, Virginia, and Washington.

4/ Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for routine maintenance.

5/ Includes imported cement.

6/ Includes cement produced from imported clinker.

7/ Excludes one additional plant that was operational January through April.

8/ Data may not add to totals shown because of independent rounding.

TABLE 3
MASONRY CEMENT PRODUCTION AND STOCKS IN THE UNITED STATES, BY DISTRICT 1/

(Thousand metric tons unless otherwise specified)

District	1995 Plants active	Production 2/	Stocks 3/ at mills, Dec. 31	1996 Plants active	Production 2/	Stocks 3/ at mills, Dec. 31
Maine, New York	4	100	18	4	102	16
Pennsylvania, eastern	6	186	38	6	170	31
Pennsylvania, western	4	81	13	4	105	16
Illinois	1	–	–	1	–	–
Indiana	4	W	W	4	W	W
Michigan	5	229	26	5	232	28
Ohio	2	W	W	2	W	W
Iowa, Nebraska, South Dakota	4	51	17	4	W	6
Kansas	3	31	10	3	24	9
Missouri	1	W	W	1	W	W
Florida	4	383	31	4	422	26
Georgia, Virginia, West Virginia	4	319	34	4	376	32
Maryland	2	W	W	2	W	W
South Carolina	2	W	W	2	286	W
Alabama	5	306	45	5	309	37
Kentucky, Mississippi, Tennessee	3	108	15	3	W	W
Arkansas, Oklahoma	4	110	19	4	117	21
Texas, northern	4	W	8	4	W	8
Texas, southern	5	98	7	5	100	7
Arizona, New Mexico	3	W	W	3	W	W
Colorado, Wyoming	2	W	W	2	W	W
Idaho, Montana, Nevada, Utah	4	W	W	4	W	W
Alaska, Hawaii	1	5	1	1	5	1
California, northern	1	W	W	1	W	W
California, southern	3	149	W	3	160	W
Oregon, Washington	3	W	W	3	W	W
Total or average 4/	84	3,603	455	84	3,469	380

W Withheld to avoid disclosing company proprietary data; included in "Total or average."

1/ Excludes Puerto Rico (did not produce any masonry cement).

2/ Includes cement made from imported clinker.

3/ Includes imported cement.

4/ Data may not add to totals shown because of independent rounding.

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TABLE 4
CLINKER CAPACITY AND PRODUCTION IN THE UNITED STATES IN 1996, BY DISTRICT

District	Active plants 1/ Process used Wet	Dry	Both	Total	Number of kilns	Daily capacity (thousand metric tons)	Average number of days routine maintenance	Apparent annual capacity 2/ (thousand metric tons)	Production 3/ (thousand metric tons)	Percent utilized
Maine, New York	3	1	--	4	5	9	60	2,911	2,741	94.2
Pennsylvania, eastern	2	5	--	7	14	13	37	4,360	3,869	88.7
Pennsylvania, western	3	1	--	4	8	6	44	1,823	1,669	91.6
Illinois	--	4	--	4	8	8	33	2,655	2,557	96.3
Indiana	2	2	--	4	8	8	29	2,865	2,355	82.2
Michigan	1	2	--	3	8	13	29	4,434	4,116	92.8
Ohio	1	1	--	2	3	3	W	W	W	88.4
Iowa, Nebraska, South Dakota	--	4	1	5	9	13	48	4,195	3,635	86.7
Kansas	2	2	--	4	11	4	34	1,364	1,619	118.7
Missouri	2	3	--	5	7	14	32	4,410	4,195	95.1
Florida	2	2	--	4	7	9	35	2,961	2,957	99.9
Georgia, Virginia, West Virginia	1	2	1	4	12	9	46	3,019	2,432	80.6
Maryland	1	2	--	3	7	5	55	1,692	1,562	92.3
South Carolina	2	1	--	3	7	7	25	2,507	2,175	86.8
Alabama	--	5	--	5	6	12	33	3,892	3,886	99.8
Kentucky, Mississippi, Tennessee	2	2	--	4	5	6	27	2,153	2,054	95.4
Arkansas, Oklahoma	2	2	--	4	10	8	20	2,756	2,506	90.9
Texas, northern	3	3	--	6	14	13	43	4,015	3,834	95.5
Texas, southern	--	4	1	5	6	13	31	4,286	4,208	98.2
Arizona, New Mexico	--	3	--	3	9	6	25	2,256	2,110	93.5
Colorado, Wyoming	1	3	--	4	7	6	45	2,066	1,828	88.5
Idaho, Montana, Nevada, Utah	4	3	--	7	10	7	34	2,093	2,079	99.3
Alaska, Hawaii	--	1	--	1	1	1	15	260	124	47.7
California, northern	--	3	--	3	3	9	56	2,637	2,509	95.1
California, southern	--	8	--	8	17	20	32	6,429	7,034	109.4
Oregon, Washington	1	2	--	3	3	4	W	W	W	127.2
Total or average 4/	35	71	3	109	205	228	36	74,155	70,361	94.9
Puerto Rico	--	2	--	2	2	5	6	1,797	1,345	74.8

W Withheld to avoid disclosing company proprietary data; included in "Total or average."
1/ Includes white cement plants.
2/ Calculated on the basis of individual company data using 365 days minus reported days for routine maintenance multiplied by the reported unrounded daily capacity.
3/ Includes production reported for plants that shut down during the year.
4/ Data may not add to totals shown because of independent rounding.

TABLE 5
RAW MATERIALS USED IN PRODUCING CEMENT
IN THE UNITED STATES 1/ 2/ 3/

(Thousand metric tons)

Raw materials	1995	1996
Calcareous:		
Limestone (includes aragonite, marble, chalk)	80,142	80,016
Cement rock (includes marl)	24,164	25,746
Coral	680	682
Aluminous:		
Clay	4,294	4,747
Shale	4,378	4,202
Other (includes staurolite, bauxite, aluminum dross, alumina, volcanic material, other)	967	1,127
Siliceous:		
Sand and calcium silicate	2,210	2,153
Sandstone, quartzite, other	741	640
Ferrous: Iron ore, pyrites, millscale, other	1,523	1,691
Other:		
Gypsum and anhydrite	3,997	4,126
Clinker, imported 4/	2,635	2,133
Blast furnace slag	130	133
Fly ash	1,396	1,261
Other, n.e.c.	82	56
Total 5/	127,339	128,713

1/ Includes Puerto Rico.
2/ Nonfuel materials only.
3/ Includes portland and masonry cement.
4/ Outside purchases by producing plants; excludes purchases of domestic clinker.
5/ Data may not add to totals shown because of independent rounding.

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TABLE 6
CLINKER PRODUCED AND FUEL CONSUMED BY THE CEMENT INDUSTRY 1/
IN THE UNITED STATES, 2/ BY PROCESS

Kiln process	Clinker produced: Plants active	Clinker produced: Quantity (thousand metric tons)	Clinker produced: Percentage of total	Fuel consumed: Coal (thousand metric tons)	Fuel consumed: Coke (thousand metric tons)	Fuel consumed: Petroleum coke (thousand metric tons)	Fuel consumed: Oil (thousand liters)	Fuel consumed: Natural gas (thousand cubic meters)	Waste fuel: Tires (thousand metric tons)	Waste fuel: Solid (thousand metric tons)	Waste fuel: Liquid (thousand liters)
1995:											
Wet	35	18,775	26.3	2,351 3/	110	503	13,624	327,798	31	62	626,436
Dry	72	50,529	70.9	5,664 3/	346	943	28,190	635,786	122	6	258,150
Both	3	1,953	2.7	225 3/	--	28	--	105,459	5	--	--
Total 4/	110	71,257	100.0	8,241 3/	455	1,475	41,814	1,069,044	158	68	884,586
1996:											
Wet	35	18,502	25.8	2,343	101	492	30,158	223,986	42	54	649,978
Dry	73	51,240	71.5	6,140	357	776	33,558	411,323	142	18	260,175
Both	3	1,964	2.7	281	--	28	--	74,343	7	--	--
Total 4/	111	71,706	100.0	8,764	458	1,295	63,716	709,652	191	72	910,153

1/ Includes portland and masonry cement. Excludes grinding plants.
2/ Includes Puerto Rico.
3/ Revised to exclude coke and petroleum coke.
4/ Data may not add to totals shown because of independent rounding.

TABLE 7
ELECTRIC ENERGY USED AT CEMENT PLANTS
IN THE UNITED STATES, 1/ BY PROCESS

Kiln process	Electric energy used: Generated by cement plants: Number of plants	Generated by cement plants: Quantity (million kilowatt-hours)	Purchased: Number of plants	Purchased: Quantity (million kilowatt-hours)	Total: Quantity (million kilowatt-hours)	Total: Percentage	Finished cement 2/ produced (thousand metric tons)	Average consumption (kilowatt-hours per ton of cement produced)
1995:								
Wet	--	--	34	2,682	2,682	24.6	19,595 r/	137 r/
Dry	5	574	70	7,355	7,930	72.7	53,389 r/	149 r/
Both	--	--	3	298	298	2.7	2,014 r/	148 r/
Total 3/	5	574	107	10,335 r/	10,909 r/	100.0	74,998 r/	145 r/
Percent of total electric energy used	--	5	--	95	--	--	--	--
Adjustments 4/	--	--	2 r/	--	--	--	1,094 r/	--
1996:								
Wet	--	--	34	2,700	2,700	24.0	19,778	137
Dry	4	500	72	7,847	8,347	68.3	55,610	150
Both	--	--	3	320	320	2.6	2,123	151
Total 3/	4	500	109	10,867	11,368	100.0	77,512	147
Percent of total electric energy used	--	4	--	96	--	--	--	--
Adjustments 4/	--	--	2	--	--	--	1,059	--

r/ Revised.
1/ Includes Puerto Rico. Excludes grinding plants.
2/ Includes portland and masonry cement.
3/ Data may not add to totals shown because of independent rounding.
4/ Tonnage of cement by two plants that did not report any electricity consumption.

TABLE 8
CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN 1/ 2/

(Thousand metric tons)

Destination and origin	Portland cement: 1995	Portland cement: 1996	Masonry cement: 1995	Masonry cement: 1996
Destination:				
Alabama	1,389	1,474	121	133
Alaska	108	100	W	W
Arizona	2,266	2,516	W	W
Arkansas	937	905	54	56
California, northern	2,984	3,226	2	4
California, southern	5,118	5,239	W	W
Colorado	1,634	1,891	21	21
Connecticut 3/	607	654	13	12
Delaware 3/	223	240	9	9

See footnotes at end of table.

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TABLE 8-Continued
CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN 1/ 2/

(Thousand metric tons)

Destination and origin	Portland cement		Masonry cement	
	1995	1996	1995	1996
District of Columbia 3/	107	115	(4/)	1
Florida	5,769	6,082	465	538
Georgia	3,045	3,179	214	233
Hawaii	358	313	5	5
Idaho	463	449	1	1
Illinois, excluding Chicago	1,439	1,538	31	35
Chicago, metropolitan 3/	1,864	1,943	45	43
Indiana	1,859	1,947	92	93
Iowa	1,429	1,601	12	12
Kansas	1,339	1,527	15	16
Kentucky	1,195	1,258	91	93
Louisiana 3/	1,747	1,751	50	53
Maine	210	212	5	5
Maryland	1,092	1,179	79	73
Massachusetts 3/	1,036	1,074	26	24
Michigan	2,712	2,992	126	143
Minnesota 3/	1,579	1,605	32	32
Mississippi	865	931	52	56
Missouri	2,234	2,269	44	41
Montana	274	273	1	1
Nebraska	982	994	9	10
Nevada	1,483	1,803	(4/)	1
New Hampshire 3/	256	275	7	7
New Jersey 3/	1,410	1,471	57	61
New Mexico	708	747	7	8
New York, eastern	491	484	29	21
New York, western	754	759	31	31
New York, metropolitan 3/	1,078	1,203	39	42
North Carolina 3/	2,218	2,259	263	273
North Dakota 3/	310	300	3	4
Ohio	3,533	3,725	181	190
Oklahoma	1,105	1,145	38	41
Oregon	1,027	1,165	(4/)	(4/)
Pennsylvania, eastern	1,806	1,840	57	60
Pennsylvania, western	1,002	1,035	66	68
Rhode Island 3/	117	111	3	3
South Carolina	1,035	1,160	106	116
South Dakota	302	333	4	4
Tennessee	1,805	1,965	193	211
Texas, northern	4,115	4,373	146	162
Texas, southern	4,225	4,413	91	90
Utah	1,286	1,267	2	3
Vermont 3/	105	111	3	3
Virginia	1,757	1,794	138	149
Washington	1,669	1,722	6	6
West Virginia	412	443	30	29
Wisconsin	1,838	2,013	35	38
Wyoming	215	196	1	1
U.S. total 5/	82,925	87,588	3,150	3,361
Foreign countries 6/	393	355	93	106
Puerto Rico	1,405	1,555	--	--
Total shipments 5/	84,724	89,498	3,243	3,467
Origin:				
United States 7/	71,750	75,995	3,185	3,416
Puerto Rico	1,405	1,555	--	--
Foreign 8/	11,568	11,948	57	51
Total shipment 5/	84,724	89,498	3,243	3,467

W Withheld to avoid disclosing company proprietary data; included with "Foreign countries."

1/ Includes cement produced from imported clinker and imported cement shipped by domestic producers, Canadian cement manufacturers, and other importers.

2/ Data are developed from monthly consolidated surveys of shipments by company and may differ from data in tables in 1, 10, 11, 12, 14, and 15, which are from annual surveys of individual plants.

3/ Has no cement plants.

4/ Less than 1/2 unit.

5/ Data may not add to totals shown because of independent rounding.

6/ Includes shipments to U.S. possessions and territories. Includes States indicated by the symbol W.

7/ Includes cement produced by domestic producers from imported clinker.

8/ Imported cement distributed in the United States by domestic producers, Canadian cement manufacturers, and other importers.

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TABLE 9
CEMENT SHIPMENTS, BY DESTINATION (REGION AND CENSUS DISTRICT) 1/ 2/

Region and Census District	Portland cement: Thousand metric tons		Portland cement: Percentage of grand total		Masonry cement: Thousand metric tons		Masonry cement: Percentage of grand total	
	1995	1996	1995	1996	1995	1996	1995	1996
Northeast:								
New England 3/	2,330	2,438	3	3	56	54	2	2
Middle Atlantic 4/	6,540	6,792	8	8	278	282	9	8
Total 5/	8,870	9,230	11	11	334	336	11	10
South:								
South Atlantic 6/	15,658	16,452	19	19	1,303	1,421	41	42
East South Central 7/	5,255	5,627	6	6	457	493	15	14
West South Central 8/	12,129	12,587	15	14	379	402	12	12
Total 5/	33,042	34,666	40	39	2,139	2,316	68	68
Midwest:								
East North Central 9/	13,245	14,159	16	16	511	541	16	16
West North Central 10/	8,174	8,628	10	10	120	118	4	4
Total 5/	21,419	22,787	26	26	,631	,659	20	20
West:								
Mountain 11/	8,330	9,140	10	10	32	35	1	1
Pacific 12/	11,264	11,765	14	13	12	14	(13/)	(13/)
Total 5/	19,594	20,905	24	23	44	49	1	1
Grand total 5/	82,925	87,588	100	100	3,150	3,361	100	100

1/ Includes imported cement shipped by importers. Excludes Puerto Rico and exported cement.
2/ Data are developed from monthly consolidated surveys of shipments by company and may differ from data in tables 1, 10, 11, 12, 14, and 15, which are from annual surveys of individual plants.
3/ New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
4/ Middle Atlantic includes New Jersey, New York, and Pennsylvania.
5/ Data may not add to totals shown because of independent rounding.
6/ South Atlantic includes Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.
7/ East South Central includes Alabama, Kentucky, Mississippi, and Tennessee.
8/ West South Central includes Arkansas, Louisiana, Oklahoma, and Texas.
9/ East North Central includes Illinois, Indiana, Michigan, Ohio, and Wisconsin.
10/ West North Central includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.
11/ Mountain includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.
12/ Pacific includes Alaska, California, Hawaii, Oregon, and Washington.
13/ Less than 1/2 unit.

TABLE 10
SHIPMENTS OF PORTLAND CEMENT FROM MILLS IN THE UNITED STATES, 1/ IN BULK AND IN CONTAINERS, BY TYPE OF CARRIER

(Thousand metric tons)

	Shipments from plant to terminal: In bulk	Shipments from plant to terminal: In containers 2/	Shipments to final domestic consumer: From plant to consumer: In bulk	Shipments to final domestic consumer: From plant to consumer: In containers 2/	Shipments to final domestic consumer: From terminal to consumer: In bulk	Shipments to final domestic consumer: From terminal to consumer: In containers 2/	Shipments to final domestic consumer: Total shipments to consumer 3/ 4/
1995:							
Railroad	10,388	64	2,396	377	951	78	3,803
Truck	2,763	222	43,917	1,922	25,964	645	72,449
Barge and boat	7,898	--	105	26	32	--	162
Other 5/	1,853	--	--	--	--	--	--
Total 3/	22,902	286	46,418	2,325	26,947	723	76,414
1996:							
Railroad	10,527	54	5,036	433	520	53	6,042
Truck	3,143	147	43,990	1,708	29,027	870	75,594
Barge and boat	7,021	--	565	3	810	--	1,378
Other 5/	1,811	--	--	--	14	2	16
Total 3/	22,502	201	49,592	2,144	30,370	927	83,033

1/ Includes Puerto Rico. Includes imported cement and cement made from foreign clinker.
2/ Includes bags and jumbo bags.
3/ Data may not add to totals shown because of independent rounding.
4/ Shipments calculated based on annual survey of plants; may differ from tables 8 and 9, which are based on consolidated company monthly data.
5/ Includes cement used at plant.

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TABLE 11
PORTLAND CEMENT SHIPPED BY PRODUCERS IN THE UNITED STATES, BY DISTRICT 1/ 2/

District	1995 3/ Quantity (thousand metric tons) 6/	1995 3/ Value 5/ Total (thousands)	1995 3/ Value 5/ Average per ton	1996 4/ Quantity (thousand metric tons) 6/	1996 4/ Value 5/ Total (thousands)	1996 4/ Value 5/ Average per ton
Maine, New York	2,916	$230,337	$78.99	3,118	$189,942	$60.92
Pennsylvania, eastern	3,899	241,352	61.90	4,095	307,830	75.17
Pennsylvania, western	1,486	99,139	66.72	1,612	112,747	69.94
Illinois	1,651	109,030	66.04	2,653	183,736	69.26
Indiana	2,510	154,462	61.54	2,570	168,032	65.38
Michigan	5,098	340,461	66.78	5,470	403,465	73.76
Ohio	985	68,237	69.28	1,013	74,100	73.15
Iowa, Nebraska, South Dakota	3,790	262,662	69.30	3,966	302,254	76.21
Kansas	1,703	107,345	63.03	1,859	128,848	69.31
Missouri	4,778	295,352	61.81	5,141	332,715	64.72
Florida	4,199	309,231	73.64	4,575	325,302	71.10
Georgia, Virginia, West Virginia	2,471	181,915	73.62	2,644	193,907	73.34
Maryland	1,796	108,230	60.26	1,924	118,832	61.76
South Carolina	2,291	161,390	70.45	2,463	193,115	78.41
Alabama	3,910	272,509	69.70	4,138	311,819	75.36
Kentucky, Mississippi, Tennessee	2,346	156,550	66.73	2,712	197,788	72.93
Arkansas, Oklahoma	2,506	158,566	63.27	2,545	170,721	67.08
Texas, northern	3,556	228,525	64.26	3,562	242,030	67.95
Texas, southern	4,908	293,380	59.78	5,152	320,441	62.20
Arizona, New Mexico	2,309	160,069	69.32	2,238	172,938	77.27
Colorado, Wyoming	1,841	149,462	81.19	2,001	160,521	80.22
Idaho, Montana, Nevada, Utah	2,432	185,221	76.16	2,398	190,588	79.48
Alaska, Hawaii, Oregon, Washington	1,520	136,986	90.09	1,493	125,137	83.79
California, northern	2,032	139,534	68.67	2,151	147,089	68.38
California, southern	6,212	357,611	57.57	6,897	415,781	60.28
Total 7/ 8/ 9/ or average	75,009	5,028,616	67.04	81,478	5,722,113	70.23
Puerto Rico	1,405	W	W	1,555	W	W

W Withheld to avoid disclosing company proprietary data.

1/ Includes cement produced from imported clinker.

2/ Includes imported cement shipped by producers.

3/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: California, Florida (2), Iowa, Michigan, Ohio, Pennsylvania, and Texas.

4/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: Florida (2) Michigan (2), Ohio, Virginia, and Washington.

5/ Values represent ex-plant (f.o.b - plant) data collected for total shipments to final customers, not for shipments by cement type. Although presented unrounded, the data incorporate estimates for some plants. Accordingly, the data should be viewed as cement value indicators.

6/ Shipments calculated based on annual survey of plants; may differ from tables 8 and 9, which are based on consolidated company monthly data.

7/ Data may not add to totals shown because of independent rounding.

8/ Does not include cement consumed at plant.

9/ Total includes imports shipped by independent importers.

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TABLE 12
MASONRY CEMENT SHIPPED BY PRODUCERS IN THE UNITED STATES, BY DISTRICT 1/

District	1995 2/			1996 3/		
	Quantity (thousand metric tons) 5/	Value 4/ Total (thousands)	Value 4/ Average per ton	Quantity (thousand metric tons) 5/	Value 4/ Total (thousands)	Value 4/ Average per ton
Maine, New York	87	$6,986	$80.30	102	$8,440	$82.75
Pennsylvania, eastern	180	13,211	73.39	181	17,783	98.25
Pennsylvania, western	80	7,394	92.43	99	10,861	109.71
Illinois, Indiana, Ohio	500	42,857	85.67	498	42,756	85.93
Michigan	224	16,369	73.08	254	22,271	87.68
Iowa, Nebraska, South Dakota	45	4,116	91.47	46	5,075	110.33
Kansas, Missouri	159	8,562	53.95	155	8,691	56.03
Florida	415	38,023	91.62	418	34,901	83.50
Georgia, Virginia, West Virginia	303	30,073	99.25	366	40,174	109.77
Maryland, South Carolina	341	28,909	84.89	400	34,901	87.19
Alabama	302	30,277	100.25	311	32,240	103.67
Kentucky, Mississippi, Tennessee	117	9,476	80.99	113	10,391	91.96
Arkansas, Oklahoma	102	7,945	77.89	110	9,487	86.25
Texas	207	16,423	87.26	215	18,289	93.89
Arizona, Colorado, Idaho, Montana New Mexico, Nevada, Utah, Wyoming	122	9,099	74.30	135	11,186	83.08
Alaska, Hawaii	5	495	99.00	4	454	113.50
California, Oregon, Washington	177	11,793	66.78	219	14,729	67.40
Total 6/ 7/ or average	3,229 r/	282,805 r/	87.58 r/	3,477	322,832	92.85

r/ Revised.

1/ Excludes Puerto Rico (did not produce any masonry cement).

2/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: California, Florida (2), Iowa, Michigan, Ohio, Pennsylvania, and Texas.

3/ Includes data for three white cement facilities as follows: California, Pennsylvania, and Texas. Includes data for grinding plants as follows: Florida (2) Michigan (2) Ohio, Virginia, and Washington.

4/ Values represent ex-plant (f.o.b - plant) data collected for total shipments to final customers, not for shipments by cement type. Although presented unrounded, the data incorporate estimated for some plants. Accordingly, the data should be viewed as cement-value indicators.

5/ Shipments calculated on the basis of annual survey of plants; may differ from tables 8 and 9, which are based on consolidated company monthly data.

6/ Data may not add to totals shown because of independent rounding.

7/ Total includes imports shipped by independent importers.

TABLE 13
AVERAGE MILL VALUE OF CEMENT IN THE UNITED STATES 1/

(Dollars per metric ton)

Year	Gray portland cement	White portland cement	All portland cement	Prepared masonry cement	All classes of cement
1995	66.25 r/	174.66	67.04 r/	85.64	67.84
1996	69.37	183.08	70.23	92.84	71.15

r/ Revised.

1/ Excludes Puerto Rico. Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges from producing plant to distribution terminal if any.

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TABLE 14
PORTLAND CEMENT SHIPMENTS IN 1996, BY DISTRICT OF ORIGIN AND TYPE OF CUSTOMER

(Thousand metric tons)

District of origin	Ready mixed concrete	Concrete product manufacturers 1/	Contractors 2/	Building material dealers	Oil well, mining, waste 3/	Government and miscellaneous 4/	Total 5/ 6/
Maine, New York	602	206	--	70	1	2,239	3,118
Pennsylvania, eastern	1,682	620	132	206	21	1,435	4,095
Pennsylvania, western	973	183	162	78	17	199	1,612
Illinois	2,035	256	163	13	187	--	2,653
Indiana	2,080	330	41	101	10	10	2,570
Michigan	2,246	660	230	277	16	2,041	5,470
Ohio	352	109	22	62	6	460	1,013
Iowa, Nebraska, South Dakota	2,824	530	372	89	57	96	3,966
Kansas	1,154	174	252	28	23	227	1,859
Missouri	3,332	448	565	140	--	657	5,141
Florida	2,737	643	276	267	--	650	4,575
Georgia, Virginia, West Virginia	1,761	456	236	183	8	--	2,644
Maryland	1,046	243	120	11	--	503	1,924
South Carolina	1,856	417	82	59	--	48	2,463
Alabama	1,765	443	222	268	--	1,440	4,138
Kentucky, Mississippi, Tennessee	1,656	252	59	29	2	715	2,712
Arkansas, Oklahoma	1,450	72	256	22	70	675	2,545
Texas, northern	1,800	351	503	101	370	437	3,562
Texas, southern	2,974	275	505	177	221	1,000	5,152
Arizona, New Mexico	1,453	316	261	66	33	107	2,238
Colorado, Wyoming	1,596	203	116	64	22	--	2,001
Idaho, Montana, Nevada, Utah	1,934	197	107	19	58	83	2,398
Alaska, Hawaii	264	21	63	21	--	--	369
California, northern	1,605	335	141	38	2	31	2,151
California, southern	4,964	1,025	149	162	82	515	6,897
Oregon, Washington	655	91	87	52	--	238	1,124
Total 5/ 6/ 7/	49,137	9,217	5,177	2,735	1,212	14,001	81,478
Puerto Rico	803	140	29	580	--	3	1,555

1/ Concrete product manufacturers include, in thousand metric tons, brick/ block,--1,655; precast,--1,138; pipe,--750; and others,--5,814. Remainder includes unspecified amounts of brick/ block, precast, and pipe.

2/ Contractors in thousand metric tons include road paving,--1,827; soil cement,--763 and other,--2,389. Remainder includes unspecified amounts of road paving, and soil cement.

3/ Oil well, mining, and waste included in thousand metric tons oil well drilling,--1,022; mining,--89; and waste stabilization,--101.

4/ Includes shipments designated as going to "unspecified" customers.

5/ Shipments calculated on the basis of annual survey of plants; may differ from tables 8 and 9, which are based on consolidated company monthly data.

6/ Data may not add to totals shown because of independent rounding.

7/ Includes imports shipped by independent importers.

TABLE 15
PORTLAND CEMENT SHIPPED FROM PLANTS IN THE
UNITED STATES TO DOMESTIC CUSTOMERS, 1/ 2/ BY TYPE

Type	1995 Quantity (thousand metric tons)	1996 Quantity (thousand metric tons)
General use and moderate heat (Types I and II), (Gray)	69,247	75,014
High early strength (Type III)	2,658	2,942
Sulfate resisting (Type V)	1,694	2,000
Block	493	416
Oil well	750	1,041
White	549	615
Blended:		
Portland-slag and portland pozzolan	754	770
Other blended cement 3/	63	63
Expansive and regulated fast setting	60	81
Miscellaneous 4/	147	89
Total 5/ 6/	76,414	83,033

1/ Includes Puerto Rico. Includes imported cement.

2/ Shipments calculated based on annual survey of plants; may differ from tables 8 and 9, which are based on consolidated company monthly data.

3/ Includes blends with fly ash and silica fume.

4/ Includes waterproof and low heat (Type IV).

5/ Data may not add to totals shown because of independent rounding.

6/ Does not include cement consumed at plant.

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TABLE 16
U.S. EXPORTS OF HYDRAULIC CEMENT AND CLINKER, 1/ BY COUNTRY

(Thousand metric tons and thousand dollars)

Country of destination	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Canada	582	40,434	611	42,193
China	2	348	17	816
Germany	15	593	22	1,814
Hong Kong	26	1,290	20	1,042
Korea, Republic of	1	89	10	536
Marshall Islands	--	6	9	400
Mexico	17	1,871	30	4,805
United Kingdom	8	513	10	539
Other	108 r/	7,831 r/	74	6,007
Total 3/	759	52,975	803	58,152

r/ Revised

1/ Includes portland and masonry cement.

2/ Free alongside ship (f.a.s.) value. The value of exports at the U.S. seaport or border port of export based on the transaction price, including inland freight, insurance, and other charges incurred in placing the merchandise alongside the carrier at the U.S. port of exportation. The value excludes the cost of loading.

3/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 17
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, 1/ BY COUNTRY

(Thousand metric tons and thousand dollars)

Country of origin	1995			1996		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Bulgaria	222	5,831	9,198	148	4,433	6,274
Canada	4,886	198,056	217,926	5,351	246,694	270,198
China	337	13,183	18,138	394	15,771	19,714
Colombia	804	30,993	38,026	924	36,520	46,872
Denmark	327	15,116	21,649	399	17,593	26,393
Greece	1,245	44,326	61,549	1,098	40,803	52,046
Italy	362	14,440	20,044	209	8,432	11,751
Mexico	850	31,938	39,491	1,272	47,736	59,390
Norway	347	12,896	17,863	226	8,181	11,032
Spain	1,501	56,336	71,906	1,595	63,274	83,739
Sweden	529	16,495	23,165	765	24,337	33,495
Venezuela	1,435	56,965	71,317	1,517	58,424	73,536
Other	1,002 r/	44,489 r/	59,253 r/	257	20,051	24,116
Total 4/	13,848	541,064	669,525	14,154	592,249	718,556

r/ Revised.

1/ Includes portland, masonry, and other hydraulic cements. Includes Puerto Rico.

2/ Customs value--price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

3/ C.i.f. (Cost, insurance, and freight)--import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

4/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER,
BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1995			1996		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
Anchorage:						
Canada	4	165	289	5	138	309
China	64	2,489	3,469	59	2,413	3,443
United Kingdom	(4/)	4	5	--	--	--
Total 3/	67	2,657	3,763	64	2,551	3,752
Baltimore:						
Brazil	(4/)	36	41	--	--	--
Greece	112	4,064	5,272	38	1,447	1,643
Netherlands	(4/)	25	29	--	--	--
Spain	42	1,482	1,482	15	551	551
United Kingdom	(4/)	130	174	(4/)	18	27
Venezuela	48	2,366	2,366	131	5,421	5,421
Total 3/	203	8,104	9,365	184	7,437	7,642
Boston: Netherlands	(4/)	23	27	--	--	--
Buffalo: Canada	651	32,703	35,358	740	37,270	39,996
Charleston:						
Germany	(4/)	13	17	--	--	--
Netherlands	--	--	--	(4/)	19	20
Spain	--	--	--	(4/)	36	39
United Kingdom	(4/)	75	103	(4/)	91	126
Venezuela	93	3,863	5,197	66	2,689	3,639
Total	93	3,951	5,317	67	2,835	3,824
Chicago:						
Japan	(4/)	80	96	(4/)	59	69
Netherlands	(4/)	6	24	--	--	--
Sweden	(4/)	4	6	--	--	--
Total 3/	(4/)	90	126	(4/)	59	69
Cleveland:						
Canada	504	17,496	18,237	497	25,320	26,051
Denmark	(4/)	2	3	--	--	--
Germany	(4/)	12	15	--	--	--
Netherlands	(4/)	76	91	(4/)	12	15
United Kingdom	--	--	--	(4/)	13	16
Total 3/	504	17,587	18,346	497	25,345	26,081
Columbia Snake:						
China	273	10,682	14,654	335	13,330	16,238
Colombia	11	385	385	18	685	867
France	(4/)	1	2	--	--	--
Total 3/	285	11,068	15,040	353	14,015	17,105
Dallas-Fort Worth: United Kingdom	--	--	--	(4/)	6	7
Detroit:						
Canada	1,518	60,156	65,627	1,647	79,423	84,419
Netherlands	--	--	--	(4/)	135	162
Taiwan	(4/)	3	3	--	--	--
Total 3/	1,518	60,159	65,629	1,647	79,559	84,581
Duluth: Canada	208	7,963	9,108	332	13,559	15,562
El Paso: Mexico	268	8,937	11,798	467	14,980	20,287
Great Falls:						
Canada	242	7,162	8,258	274	11,548	13,435
Japan	--	--	--	(4/)	2	6
United Kingdom	(4/)	15	19	(4/)	16	25
Total 3/	242	7,178	8,277	275	11,566	13,465
Honolulu:						
Australia	114	4,534	6,177	42	1,499	2,141
Belgium	--	--	--	(4/)	15	19
France	(4/)	12	17	(4/)	21	26
New Zealand	22	680	1,043	--	--	--
Venezuela	--	--	--	115	3,491	5,792
Total	137	5,227	7,237	157	5,027	7,977

See footnotes at end of table.

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TABLE 18--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1995			1996		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
Houston-Galveston:						
Colombia	24	884	1,380	46	1,739	2,729
Denmark	--	--	--	30	1,067	1,438
France	--	--	--	(4/)	83	99
Japan	(4/)	65	77	(4/)	46	55
Spain	574	19,985	25,750	675	24,872	32,188
United Kingdom	(4/)	50	63	(4/)	41	55
Venezuela	--	--	--	27	899	1,120
Total	598	20,984	27,270	780	28,748	37,684
Laredo:						
China	(4/)	3	4	--	--	--
Mexico	51	4,755	5,211	69	7,121	7,590
Total	52	4,758	5,215	70	7,121	7,590
Los Angeles:						
Croatia	1	165	251	--	--	--
Denmark	--	--	--	(4/)	3	5
Japan	(4/)	70	79	--	--	--
Mexico	225	8,229	10,049	382	13,945	17,027
New Zealand	(4/)	265	332	--	--	--
United Kingdom	(4/)	5	8	--	--	--
Total 3/	227	8,734	10,719	382	13,948	17,031
Miami:						
Belgium	3	251	340	2	251	340
Brazil	(4/)	5	5	--	--	--
Canada	--	--	--	24	871	1,153
Colombia	224	9,221	11,509	--	--	--
Denmark	22	1,119	1,949	44	1,942	3,290
Germany	(4/)	9	12	--	--	--
Portugal	--	--	--	(4/)	23	24
Spain	350	15,732	19,364	435	19,166	27,430
Sweden	337	10,044	14,118	441	13,529	18,471
United Kingdom	--	--	--	(4/)	1	1
Venezuela	63	2,170	3,040	189	7,439	9,913
Total 3/	999	38,550	50,337	1,136	43,223	60,622
Milwaukee: Canada	188	6,361	6,561	219	9,069	10,279
Minneapolis: Germany	(4/)	11	13	(4/)	12	13
Mobile:						
Bulgaria	162	4,315	6,811	122	3,368	4,863
Canada	--	--	--	163	5,087	6,948
France	63	1,936	2,064	--	--	--
Greece	69	2,086	2,947	73	2,446	3,317
Tunisia	25	695	1,055	--	--	--
Venezuela	82	2,705	3,601	25	819	1,007
Total 3/	401	11,737	16,478	383	11,721	16,135
New Orleans:						
Austria	--	--	--	(4/)	6	8
Bulgaria	35	874	1,338	--	--	--
Canada	145	4,293	5,745	88	3,065	4,047
China	--	--	--	(4/)	28	33
Colombia	169	6,414	8,528	120	5,131	6,768
Croatia	5	605	885	5	605	873
France	400	15,359	20,497	10	1,576	1,906
Greece	359	12,560	17,385	282	10,601	13,993
Italy	362	14,440	20,044	208	8,431	11,745
Netherlands	(4/)	6	8	--	--	--
Norway	103	3,548	5,180	--	--	--
Spain	37	1,360	1,771	9	340	438
Sweden	39	1,302	1,887	236	7,837	10,906
Tunisia	52	1,462	2,111	--	--	--
Turkey	213	6,530	9,702	34	1,271	1,592

See footnotes at end of table.

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TABLE 18--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER,
BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1995			1996		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
New Orleans--Continued:						
Venezuela	6	278	369	--	--	--
Total 3/	1,928	69,033	95,448	993	38,889	52,309
New York:						
France	(4/)	5	6	--	--	--
Greece	182	6,652	8,952	206	7,455	8,215
Italy	--	--	--	(4/)	1	6
Japan	--	--	--	(4/)	7	7
Netherlands	(4/)	79	83	(4/)	226	241
Norway	245	9,348	12,684	226	8,181	11,032
Spain	218	8,246	10,472	236	10,465	13,136
United Kingdom	(4/)	50	61	--	--	--
Total 3/	645	24,379	32,258	668	26,335	32,637
Nogales: Mexico	303	9,733	12,117	351	11,189	13,944
Norfolk:						
Croatia	(4/)	4	9	--	--	--
Denmark	236	9,366	12,245	214	8,460	11,079
France	45	7,294	8,282	45	8,103	8,914
Greece	492	17,908	25,466	438	16,756	22,029
Netherlands	(4/)	144	161	(4/)	87	97
United Kingdom	(4/)	8	11	(4/)	124	173
Venezuela	--	--	--	5	208	213
Total 3/	773	34,725	46,175	703	33,737	42,504
Ogdensburg:						
Canada	353	12,446	13,752	260	8,789	9,679
Netherlands	--	--	--	(4/)	56	69
United Kingdom	(4/)	12	12	--	--	--
Total	354	12,458	13,764	261	8,845	9,748
Pembina: Canada	167	7,024	8,104	143	6,812	7,724
Philadelphia:						
Germany	(4/)	76	89	(4/)	23	23
Japan	(4/)	54	65	(4/)	12	15
New Zealand	(4/)	66	85	--	--	--
United Kingdom	--	--	--	(4/)	10	22
Total	(4/)	196	239	(4/)	44	60
Portland: Canada	8	410	526	10	478	581
Providence: Spain	35	1,247	1,464	--	--	--
San Diego: Mexico	3	281	312	4	501	542
San Francisco:						
France	(4/)	30	34	--	--	--
Germany	--	--	--	(4/)	11	15
Japan	(4/)	36	44	(4/)	49	63
New Zealand	1	1,138	1,417	1	703	852
United Kingdom	(4/)	15	16	--	--	--
Total 3/	1	1,220	1,512	1	764	929
San Juan:						
Belgium	12	931	1,582	4	341	583
Canada	26	937	1,578	--	--	--
Colombia	42	1,720	1,872	--	--	--
Denmark	9	754	1,260	16	1,314	2,293
Luxembourg	--	--	--	5	439	764
Mexico	(4/)	3	4	--	--	--
Netherlands	(4/)	28	49	--	--	--
Spain	(4/)	8	11	119	4,044	4,863
Venezuela	(4/)	2	2	43	1,890	2,332
Total 3/	90	4,383	6,358	188	8,029	10,836
Savannah:						
Bahamas, The	6	244	247	--	--	--
Bulgaria	24	643	1,049	26	1,064	1,410
Canada	--	--	--	78	2,389	3,335
Colombia	--	--	--	19	1,027	1,181

See footnotes at end of table.

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TABLE 18--Continued
U.S. IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER,
BY CUSTOMS DISTRICT AND COUNTRY

(Thousand metric tons and thousand dollars)

Customs district and country	1995			1996		
		Value			Value	
	Quantity	Customs 1/	C.i.f. 2/	Quantity	Customs 1/	C.i.f. 2/
Savannah--Continued:						
Denmark	3	162	298	13	852	1,420
Greece	30	1,056	1,525	--	--	--
Ukraine	--	--	--	--	--	--
United Kingdom	30	749	1,246	64	2,310	2,460
Venezuela	91	3,274	3,691	106	3,801	5,134
Total 3/	184	6,127	8,057	307	11,443	14,939
Seattle:						
Canada	762	36,158	38,719	744	36,518	38,962
China	(4/)	9	11	--	--	--
Colombia	149	5,457	5,540	198	7,769	11,244
Japan	(4/)	46	54	(4/)	20	24
Total 3/	911	41,671	44,323	942	44,307	50,230
St. Albans:						
Canada	110	4,780	6,065	99	5,327	6,271
Netherlands	(4/)	117	136	(4/)	123	143
Total 3/	110	4,897	6,201	100	5,450	6,413
Tampa:						
Canada	--	--	--	27	1,032	1,445
Colombia	184	6,911	8,812	520	20,019	23,916
Denmark	58	3,712	5,894	83	3,955	6,870
France	(4/)	3	3	--	--	--
Greece	--	--	--	61	2,099	2,849
Spain	244	8,275	11,591	105	3,800	5,095
Sweden	152	5,147	7,154	88	2,970	4,118
Turkey	--	--	--	34	1,201	1,595
Venezuela	883	34,960	43,529	751	29,388	36,197
Total 3/	1,522	59,008	76,983	1,669	64,463	82,086
U.S. Virgin Islands:						
British Virgin Islands	--	--	--	1	98	118
Colombia	--	--	--	3	150	167
Netherlands Antilles	2	64	67	5	167	183
Panama	4	73	98	--	--	--
Trinidad and Tobago	--	--	--	3	114	119
Venezuela	32	1,628	1,847	59	2,378	2,769
Total 3/	38	1,765	2,012	70	2,907	3,356
Wilmington:						
Netherlands	(4/)	7	13	(4/)	6	12
Venezuela	139	5,719	7,675	--	--	--
Total 3/	139	5,726	7,688	(4/)	6	12
Grand total 3/	13,848	541,064	669,525	14,154	592,249	718,556

1/ Customs value- price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

2/ C.i.f. (Cost, insurance, and freight)--import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry. It is computed by adding "freight" to the "customs value."

3/ Data may not add to totals shown because of independent rounding.

4/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 19
U.S. IMPORTS FOR CONSUMPTION OF GRAY PORTLAND CEMENT 1/, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1995			1996		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Canada	3,342	136,923	152,131	3,953	182,457	198,857
China	337	13,170	18,123	393	15,743	19,682
Colombia	645	25,404	31,358	685	27,734	35,737
Denmark	238	9,529	12,543	303	11,803	16,000
Greece	1,140	41,018	56,839	983	36,949	46,822
Italy	362	14,440	20,044	208	8,432	11,751
Mexico	784	25,527	32,414	1,178	37,470	48,367
Norway	315	11,349	15,851	218	7,410	10,176
Spain	1,426	49,986	64,756	1,428	53,769	72,737
Sweden	529	16,492	23,159	765	24,337	33,495
Turkey	138	4,443	6,560	68	2,471	3,187
Venezuela	924	37,833	48,002	944	38,556	46,530
Other	327	11,571	15,281	41	1,816	1,999
Total 4/	10,507	397,685	497,061	11,167	448,947	545,340

1/ Includes imports into Puerto Rico.

2/ Customs value--price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

3/ C.i.f. (Cost, insurance, and freight)--import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

4/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 20
U.S. IMPORTS FOR CONSUMPTION OF WHITE CEMENT 1/, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1995			1996		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Belgium	14	1,176	1,915	6	591	923
Canada	167	13,888	14,603	135	12,170	12,700
Colombia	20	805	834	--	--	--
Denmark	89	5,585	9,103	96	5,787	10,389
Luxembourg	--	--	--	6	439	764
Mexico	63	6,095	6,721	91	9,995	10,732
Norway	7	707	794	8	771	856
Spain	76	6,342	7,139	48	5,425	6,101
Other	(4/)	256	298	(4/)	228	244
Total 5/	436	34,854	41,407	390	35,406	42,709

1/ Includes imports into Puerto Rico.

2/ Customs value--price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

3/ C.i.f. (Cost, insurance, and freight)--import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

4/ Less than 1/2 unit.

5/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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TABLE 21
U.S. IMPORTS FOR CONSUMPTION OF CLINKER, 1/ BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	1995			1996		
		Value			Value	
	Quantity	Customs 2/	C.i.f. 3/	Quantity	Customs 2/	C.i.f. 3/
Australia	114	4,534	6,177	42	1,499	2,141
Bulgaria	222	5,831	9,198	148	4,433	6,274
Canada	1,375	46,658	50,560	1,253	50,345	56,695
Colombia	139	4,785	5,834	239	8,785	11,135
France	163	8,062	10,061	53	8,065	9,039
Greece	104	3,308	4,709	115	3,854	5,224
Spain	--	--	--	119	4,044	4,863
Tunisia	78	2,157	3,166	--	--	--
Turkey	75	2,087	3,142	--	--	--
Venezuela	503	18,377	22,501	572	19,861	26,996
Other	83 r/	2,875 r/	4,394 r/	6	635	906
Total 4/	2,858	98,674	119,742	2,547	101,521	123,273

r/ Revised.

1/ For all types of hydraulic cement. Includes imports into Puerto Rico.

2/ Customs value-- price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

3/ C.i.f. (Cost, insurance, and freight)-- import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

4/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 22
HYDRAULIC CEMENT: WORLD PRODUCTION BY COUNTRY 1/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Afghanistan e/	115	115	115	115	116
Albania e/	200	200	200	200	200
Algeria	6,400	6,400 e/	6,060	6,822 r/	7,000
Angola e/	300	250	300	300	300
Argentina	5,051	5,647	6,306	5,447 r/	5,117 2/
Armenia	400	200	100	228 r/	282 2/
Australia e/	5,412 2/	5,500	6,500 r/	6,500 r/	6,500
Austria	5,031	4,941	4,828 r/	3,843 r/	4,000
Azerbaijan	800	600	500	200	200 2/
Bahrain	220	225	225 e/	197 r/	193 2/
Bangladesh 3/	273	275	280 e/	280 e/	285
Barbados	175 e/	62	78	80 e/	80
Belarus	2,300	1,900	1,488	1,235	1,467 2/
Belgium	8,073	7,612	8,000 e/	8,000 e/	8,000
Benin e/	370	380	380	380	380
Bhutan	116	108	120 e/	140 e/	160
Bolivia	600	654	768 r/	869 r/	934 2/
Bosnia and Herzegovina e/	150	150	150	150	200
Brazil	23,903	24,843	25,330 r/	28,256 r/	34,597
Brunei	--	--	--	--	100
Bulgaria	2,132	2,007	2,200	2,070 r/	2,100
Burma	464	400	470	517	505 2/
Cameroon e/	620 r/	620 r/	620 r/	620 r/	600
Canada	5,698	6,672	10,584	10,440 r/	11,050 p/
Chile	2,645	3,021	2,995	3,275 r/	3,634 2/
China	308,220	367,880	421,180	475,910 r/	490,000 2/
Colombia	6,807	7,930	9,322	9,624	8,346 2/
Congo e/	115 2/	114	114	100	100
Costa Rica	700 e/	860	940	990 e/	990
Côte d'Ivoire e/	510	500	500	500	500
Croatia	1,768	1,683	2,055 r/	1,708 r/	1,842 2/
Cuba	2,000 e/	1,049	1,081	1,524 r/	1,453 2/

See footnotes at end of table.

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TABLE 22--Continued
HYDRAULIC CEMENT: WORLD PRODUCTION BY COUNTRY 1/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Cyprus	1,131	1,089	1,053	1,021	1,025
Czech Republic 4/	XX	5,393	5,303	4,825	5,011 2/
Czechoslovakia 5/	8,500	XX	XX	XX	XX
Denmark (sales)	2,072	2,270	2,430	2,584 r/	2,629 2/
Dominican Republic	1,365	1,271	1,276	1,453	1,500
Ecuador	2,250 e/	2,098	2,164	2,300 e/	2,677 2/
Egypt	17,000	16,000	16,000 e/	17,665 r/	18,000
El Salvador	419	861	850	875 e/	948 2/
Eritrea e/ 6/	XX	30	30 r/	50 r/ 2/	41 2/
Estonia	600 e/	500 e/	402	417	400
Ethiopia	300	270 e/	260	611	600
Fiji	84	80	94	91 r/	92
Finland	1,129	835	864	907 r/	947 2/
France	21,165	20,464	21,296	19,692	20,000
Gabon	116	132	126 e/	130 e/	130
Georgia	500	300	100	100 e/	100
Germany	37,529	36,649	40,380	40,000 e/	40,000
Ghana	1,024	1,203	1,346	1,400 e/	1,400
Greece	10,668	12,618	12,636	12,000 e/	12,000
Guadeloupe e/	235	230	230	230	230
Guatemala	1,400 e/	1,119	1,200 r/	1,200 r/ e/	1,090 2/
Haiti e/	200	100	75	50	50
Honduras	650 e/	723	1,100 r/ e/	1,140 r/	960
Hong Kong	1,643	1,712	1,927	1,913	2,027 2/
Hungary	2,236	2,533	2,813	2,875 r/	2,776 2/
Iceland	100	86	81	82	80
India e/	50,000	53,812 2/	57,000 r/	62,000 r/	76,220 2/
Indonesia	17,280	18,934	21,907 r/	23,129 r/	25,000
Iran e/	15,200	16,000	16,000	16,300	16,500
Iraq e/	2,000 r/	2,000 r/	2,000 r/	2,108 r/ 2/	2,100
Ireland e/	1,600	1,600	1,550	1,500	1,500
Israel	3,960 r/	4,536 r/	4,800 r/	4,800 r/ e/	4,800
Italy	41,347	34,771	33,192	33,715 r/	34,000
Jamaica	475	451	445	523	555
Japan	88,253	88,046	91,624	90,474	94,492 2/
Jordan	3,134	3,514	4,000 e/	3,508 r/	3,500
Kazakstan	6,400	4,000	2,000	2,616 r/	2,500
Kenya	1,508	1,417	1,420 e/	1,500 e/	1,500
Korea, North e/	17,000	17,000	17,000	17,000	17,000
Korea, Republic of	44,444	47,313	50,730	55,130	57,334 2/
Kuwait	533	500 e/	1,000 e/	1,950 r/	2,000
Kyrgyzstan	1,100	700	400	300	500 2/
Laos e/	7	7	10	10	10
Latvia	400 e/	300 e/	244	203 r/	270 2/
Lebanon e/	1,500	3,000 r/	3,450 r/	3,538 r/ 2/	3,500
Liberia e/	8 2/	8	--	--	--
Libya	2,300	2,300 e/	2,700 r/ e/	3,210 r/	3,550 2/
Lithuania	1,500 e/	1,000 e/	736	649	600
Luxembourg e/	600	600	620	600	600
Macedonia	516	499	486	524 r/	550
Madagascar e/	60	60	60	60	60
Malawi	112	127	122	139	140
Malaysia	8,366	8,797	9,928	10,713 r/	12,335 2/
Mali e/	20	20	20	20	20
Martinique e/	240	220	225	225	225
Mauritania	122	111	374	120 r/	120
Mexico	26,880	27,120	29,700	23,366 r/	22,829 2/
Moldova	700	100	39	49	70 2/
Mongolia	133	82	86	109	106 2/
Morocco	6,340	6,350 e/	6,500 e/	6,401 r/	6,400
Mozambique e/	30	20	20	20	30
Nepal	238 r/	274 r/	316 r/	327 r/	343 2/
Netherlands e/	3,300 2/	3,400	3,400	3,400	3,300
New Caledonia e/	90 2/	90	90	100	100

See footnotes at end of table.

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TABLE 22--Continued
HYDRAULIC CEMENT: WORLD PRODUCTION BY COUNTRY 1/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
New Zealand e/	579 2/	800 r/	1,000 r/	1,000 r/	1,000
Nicaragua	277	255	309	350 e/	350
Niger e/	29 2/	29	30	30	30
Nigeria e/	3,500	3,500	2,600 2/	3,000 r/ e/	3,000
Norway	1,266	1,344	1,444	1,613 r/	1,600
Oman	970	1,000 e/	1,200 e/	1,177 r/	1,200
Pakistan	7,793	8,321	8,100	8,586	8,900
Panama	250 e/	571	615	350 e/	350
Paraguay	325 r/ e/	490	570	635 r/	620 2/
Peru e/	2,090 r/	2,500 r/	3,000 r/	3,000 r/	3,848 2/
Philippines	6,667	7,962	10,400 r/ e/	10,600 r/	12,000
Poland	11,908	12,228	13,834	13,884	13,879 2/
Portugal	7,638	7,570 r/	7,780 r/	7,770 r/	8,300
Qatar	544	550 r/ e/	600 r/ e/	667 r/	690 2/
Romania	6,271	6,240	5,998	6,842 r/	6,858 2/
Russia	61,700	49,900	37,200	36,500 r/	27,800 2/
Rwanda e/	60	60	10	5 2/	10
Saudi Arabia	15,324	15,300 e/	15,000 r/ e/	15,773 r/	16,437 2/
Senegal	601	590	590 e/	590 e/	590
Serbia and Montenegro	2,036	1,088	1,612	1,696	2,205 2/
Singapore e/	1,900	2,980 r/	3,100 r/	3,200 r/	3,300
Slovakia e/ 4/	XX	2,500	2,500	2,500	2,500
Slovenia	801 r/	707 r/	898 r/	991 r/	1,000
Somalia e/	25	25	25	25	30
South Africa	7,028	7,356	7,905	9,071	9,400
Spain (including Canary Islands)	24,615	22,878	25,150	26,423 r/	25,157 2/
Sri Lanka	817	676	925	900 e/	905
Sudan e/	250	250	250	391 r/ 2/	380
Suriname e/	50	50	50	50	50
Sweden	2,289	2,200	2,100 e/	2,539 r/	2,447 2/
Switzerland e/	4,260 2/	4,000	4,300 r/	4,400 r/	4,400
Syria	3,700	4,500	4,500 r/ e/	4,463 r/	4,100
Taiwan	21,644	23,971	22,722	22,478	21,537 2/
Tajikistan	400	300	200	100	50 2/
Tanzania e/	540	540	490	800	800
Thailand	21,832	26,870	29,900 r/ e/	34,900 r/ e/	35,000
Togo e/	350	350	350	350	350
Trinidad and Tobago	482	528 r/	583	559 r/	617 2/
Tunisia	3,999	4,269	4,606 r/	4,938 r/	4,567 2/
Turkmenistan	1,100	1,100	700	437 r/	451 2/
Turkey	28,607	31,241	29,493	33,143 r/	32,500
Uganda e/	50	50	125	90 r/	100
Ukraine	20,100	15,000	11,400	7,600 r/	5,000 2/
United Arab Emirates	3,800	4,000 e/	5,000 e/	5,918 r/	6,000
United Kingdom	11,006	11,039	12,493	11,805 r/	11,600
United States (including Puerto Rico) 7/	70,883	75,117	79,353	78,320	80,818 2/
Uruguay e/	500	500	700	600 2/	685 2/
Uzbekistan	5,900	5,300	4,800	3,400 r/	5,000 2/
Venezuela	6,585	6,842	7,100 r/ e/	7,200 r/ e/	7,300
Vietnam e/	4,000 r/	4,200 r/	4,700 r/	5,200 r/	5,700
Yemen	800	800 e/	800 e/	1,088 r/	1,040 2/
Zaire	174	149	50 r/ e/	25 r/ e/	10
Zambia	347	350 e/	280	250 r/ e/	350
Zimbabwe e/	900	1,000	1,070 r/ 2/	1,000	1,150 2/
Total e/ 8/	1,231,143 r/	1,292,379 r/	1,372,427 r/	1,443,689 r/	1,484,564

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ Table includes data available through Aug. 4, 1997. Data may include clinker exports for some countries.

2/ Reported figure.

3/ Data are for the year ending June 30 of that stated.

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Dissolved Dec. 31, 1992.

6/ Eritrea became an independent country in May 1993.

7/ Portland and masonry cement only.

8/ Data may not add to totals shown because of independent rounding.

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CHROMIUM

By John F. Papp

In the United States, chromium apparent consumption was about 480,000 tons of contained chromium. Supply consisted of recycled and imported chromium materials—about 579,000 tons, gross weight, of stainless steel scrap was recycled, and about 753,000 tons of chromite ore and chromium ferroalloys, chemicals, and pigments valued at about $463 million was imported. The United States exported about 136,000 tons of chromium materials valued at about $111 million. Compared with those of 1995, the quantity and value of chromium materials imports decreased while exports increased.

The reported consumption of chromite ore by the chemical, metallurgical, and refractory industries decreased; consequently imports also decreased. Reported consumption of chromium ferroalloys decreased, as did imports.

Chromium has a wide range of uses in metals, chemicals, and refractories. Its use in iron, steel, and nonferrous alloys enhances hardenability and resistance to corrosion and oxidation; the production of stainless steel and nonferrous alloys are two of its more important applications. Other applications are in alloy steel, plating of metals, pigments, leather processing, catalysts, and surface treatments.

Because the United States has no chromite ore reserves and a small reserve base, domestic supply has been a concern during every national military emergency since World War I. World chromite resources, mining capacity, and ferrochromium production capacity are concentrated in the Eastern Hemisphere. In recognition of the vulnerability of long supply routes during a military emergency, the National Defense Stockpile (NDS) contains chromium in various forms, including chromite ore, chromium ferroalloys, and chromium metal. As a result of improved national security, stockpile goals have been reduced, and inventory is being sold. Recycling is the only domestic supply source of chromium.

The U.S. Geological Survey (USGS) has conducted mineral-resource-surveys of the United States to assess the potential for occurrences of chromium and other mineral resources. Alternative materials research is conducted by the National Aeronautics and Space Administration, the National Institute of Standards and Technology, the U. S. Department of Defense, and the U. S. Department of Energy.

Chromium is an essential trace element for human health. Some chromium compounds, however, are acutely toxic, chronically toxic, and/or carcinogenic. Chromium releases into the environment are regulated by the U. S. Environmental Protection Agency (EPA). Workplace exposure is regulated by the Occupational Safety and Health Administration.

World chromite ore reserves are more than adequate to meet anticipated world demand.

Legislation and Government Programs

The Defense Logistics Agency (DLA) disposed of chromium materials under its fiscal year 1996 (October 1, 1995, through September 30, 1996) Annual Materials Plan (AMP). DLA's fiscal year 1996 AMP (as revised in April) set maximum disposal goals for chromium materials at 90,700 metric tons of chemical-grade chromite ore, 499,000 tons of metallurgical-grade chromite ore, 90,700 tons of refractory-grade chromite ore, and 22,700 tons of chromium ferroalloys. DLA's fiscal year 1997 calls for the disposal of 90,700 tons of chemical-grade chromite ore, 227,000 tons of metallurgical-grade chromite ore, 90,700 tons of refractory-grade chromite ore, and 22,700 tons of chromium ferroalloy. At the end of 1996, the NDS contained 2.2 million tons of chromium material comprising 1.2 million tons of chromite ore, 1.1 million tons of chromium ferroalloys, and 7,700 tons of chromium metal. *(See table 8.)*

EPA reported chromium releases and transfers from manufacturing and fabrication facilities. *(See table 2.)*

Production

The major marketplace chromium materials are chromite ore and chromium ferroalloys, metal, and chemicals. The United States produced chromium ferroalloys, metal, and chemicals, but no chromite ore.

Domestic data for chromium materials are developed by the USGS by means of two separate surveys—"Chromite Ores and Chromium Products" (consumers, monthly) and "Ferroalloys" (producers, annual). Production by the metallurgical companies listed in table 3 represented 100% of the domestic production shown in the current year of table 4.

Chrome Corporation of America planned to develop ferrochromium production facilities in Canada and then to develop stainless steel production capacity there. The company also planned to purchase a 6-megawatt direct-current furnace (Metal Bulletin, 1996).

Macalloy Corp. started a new, $3.5 million briquetting facility. This facility will permit Macalloy to use lower cost chromite ore fines and to increase ferrochromium production capacity from 55,000 to 60,000 tons per year (Ryan's Notes, 1996a, 1996b).

American Chrome & Chemicals Inc. started up a new sodium dichromate production process. Traditionally, sodium dichromate is produced from sodium chromate by acidification. American Chrome's new process will make the conversion electrolytically. The electrolytic process is cleaner and increases

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American Chrome's production capacity from 50,000 to a range of 55,000 to 60,000 tons (Chemical Marketing Reporter, 1996).

The man who established the first chromite mines in the United States and started the first U.S. chromium chemicals plant, the Baltimore Chrome Works, in Baltimore, MD, in 1845, Isaac Tyson, Jr. (1792-1861), was inducted into the National Mining Hall of Fame and Museum in Leadville, CO. He studied geology, mineralogy, and chemistry n France, where chromium had been discovered in 1797. Some of Tyson's mines are preserved in the Soldiers Delight environmental area northwest of Baltimore.

Consumption

Domestic consumption of chromite ore and concentrate was 282,000 tons. Chromium has a wide range of uses in the three primary consumer groups—the metallurgical, refractory, and chemical industries.

In the metallurgical industry, its principal use was in stainless steel. Of the 333,000 tons of chromium ferroalloys, metal, and other chromium-containing materials reported as being consumed, stainless steel accounted for 72.9%; full-alloy steel, 9.31%; carbon steel, 4.15%; high-strength, low-alloy, and electric, 3.44%; tool steel, 1.52%; cast iron, 1.00%; superalloys, 3.24%; and other end uses, 4.43%. The primary use of chromium in the refractory industry was in the form of chromite to make refractory bricks to line metallurgical furnaces.

The chemical industry consumed chromite for manufacturing sodium dichromate, chromic acid, and other chromium chemicals and pigments. A wide range of chromium chemicals are made sodium dichromate. *(See tables 5 and 6.)*

Stocks

Domestic consumer stocks of chromite ore at consumers' plants reported by consumers to the USGS was 173,000 tons. At the 1996 rate of annual chromite ore consumption, these stocks represented 7.4 months of supply. Producer and consumer stocks of chromium ferroalloys, metal, and other chromium materials were 6,450 and 27,600 tons, respectively. At the 1996 rate of annual chromium ferroalloy, metal, and other chromium material consumption, producer plus consumer stocks represented 1.2 months of supply. In addition to privately held stocks, the government maintained the NDS. *(See tables 4, through 8.)*

Prices

Chromium materials are not openly traded. Purchase contracts are confidential information between buyer and seller. Trade journals, however, report composite prices that are based on interviews with buyers and sellers, and importers declare the value of the materials they trade. Thus, industry publications and U.S. import data are sources of chromium material prices and values, respectively. *(See tables 1, 9, and 10 and figures 1 and 2.)*

Foreign Trade

Chromium material exports from and imports to the United States included chromite ore and chromium chemicals, ferroalloys, metal, and pigments. *(See tables 11 through 14.)* The amount of foreign trade of these chromium materials, measured in dollars, was$111 million for exports and $463 million for imports.

World Review

The major world producers of chromite ore are India, Kazakstan, South Africa, and Turkey. Also significant but smaller are Brazil, Finland, and Zimbabwe. Most chromite ore is smelted in an electric arc furnace to produce ferrochromium for use by the metallurgical industry. Stainless steel manufacture is the major end use of ferrochromium. A small amount of chromite is kiln roasted to produce sodium bichromate, a chemical industry product. A very small amount of chromite ore is used, without chemical modification, as a refractory material. The major producer of ferrochromium is South Africa. China, Finland, India, Japan, Kazakstan, and Zimbabwe are smaller but significant producers. The major producers of stainless steel—Europe (especially Western Europe and Scandinavia), Japan, and the United States—account for about 70% of world production. The major world producers of chromium chemicals are Kazakstan, Russia, the United Kingdom, and the United States. *(See tables 17 through 21.)*

The ferrochromium industry developed in close proximity to the stainless steel industry and later moved to chromite-producing areas. The chromium industry operated with supply capacity in excess of demand. The last time demand exceeded supply was in 1989-90 when ferrochromium demand exceeded supply, causing prices to increase appreciably. The industry used its profits from the price increase in 1989-90 to expand capacity by about 15% in 1991-92. Capacity expansions took place primarily in chromite-producing countries; South Africa was the major benefactor. With a growth rate in the consumption of stainless steel of about 3% per year, it would take an estimated 5 years of average growth in the demand for stainless steel to bring ferrochromium supply and stainless steel demand back into equilibrium. The dissolution of the former Soviet Union (FSU) in 1991 and subsequent reorganization resulted in declining chromium demand in the FSU but no loss of chromium-material production capacity. As a result, significant quantities of chromium raw materials, including chromite ore, ferrochromium, chromium chemicals, and chromium-containing scrap, entered Western markets from the FSU. The integration of the former Eastern Block with the West exacerbated the already excess production capacity in the West. During this same time period, China began to use its ferroalloy production capacity for ferrochromium production.

In 1992 and 1993, significant rationalizations took place in western chromite mining and ferrochromium industries. Not all added capacity from 1991-92 could be brought into production

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or, if brought into production, could be fully utilized. The South African chromite ore and ferrochromium industries operated at between 50% and 60% of design capacity to reduce supply in excess of world demand. Several ferrochromium producers either idled their furnaces or converted them to ferromanganese production. The ferrochromium industry in Japan continued to be rationalized.

As 1994 drew to a close, the chromium material supply from Kazakstan and Russia diminished. Western stainless steel demand for chromium materials strengthened appreciably. Chromium demand moved closer to balance with supply, and ferrochromium prices started to recover. Companies planned to restart their furnaces, thereby increasing ferrochromium production. Even before all existing ferrochromium production capacity could be brought back into production, some new furnaces were planned in South Africa, and chromium recovery from slag processes were planned or implemented.

Further vertical integration of the chromium industry is taking place as Finland and South Africa increase their stainless steel production capacities. Two industry processes that improve chromium recovery efficiency were evolving—chromium recovery from slag in the ferrochromium industry and supply of molten ferrochromium to stainless steel industry.

In 1995, demand for chromium resulting from strong growth in the production of stainless steel that started in 1994 resulted in the strengthening of chromite ore and ferrochromium prices. Ferrochromium production capacity was increased in South Africa through the renovation of idle equipment and the startup of new furnaces. Construction of more capacity was started. Chromite mine capacity was increased or planned to meet demand from current and future ferrochromium consumers. Vertical integration of the chromium industries of Finland and South Africa were implemented, resulting in increased stainless steel production capacity, especially in South Africa. By yearend, world demand for stainless steel decreased as did ferrochromium prices.

In 1996, new furnaces were brought into production in South Africa and new ferrochromium recovery from slag processes were brought into production in South Africa and Zimbabwe. Southern African ferrochromium producers continued to enter into joint ventures with Asian stainless-steel-producing companies. After two years of double digit annual growth in the production of stainless steel, 1996 saw a decline in production. Chromite ore and high-carbon ferrochromium prices trended downward during the year. Low-carbon ferrochromium prices peaked about midyear and ended lower than they began.

Industry Structure.—The chromium industry comprised primarily producers of chromite ore, ferrochromium, and stainless steel as well as chromium chemical and chromite refractory. Finland, India, and Republic of South Africa are countries that have a fully vertically integrated chromium industry. These countries mine chromite ore, produce ferrochromium and stainless steel under a single ownership structure. Brazil, China, Japan, Kazakstan, Russia, Turkey, and Zimbabwe are countries that have partially integrated chromium industries. These countries either mine chromite ore and produce ferrochromium or produce ferrochromium and stainless steel under a single ownership structure.

In Finland, Outokumpu Oy, a major share of which is state-owned, owns and operates the only chromite mining, ferrochromium production, and stainless steel production facilities, making it completely vertically integrated. In India, chromite mining and ferrochromium production are mostly vertically integrated. Ferro Alloys Corp. is the only stainless steel producer in India that is fully vertically integrated from chromite ore mining through ferrochromium and stainless steel production. The chromium industry is comprised large and small producers; about 20 chromite mines produced ore. Major ferrochromium plants are licenced, and small plants, of which there are many, are independent. There are many small chromium chemical plants in India. In the Republic of South Africa, chromium-related companies are privately owned. Typically, major shares of a company are owned by other companies, and the remainder, if any, is openly traded. Samancor Ltd. owns and operates chromite mining and ferrochromium production and co-owns major stainless steel production facilities. Other chromite operations in South Africa are also vertically integrated. For example, Bayer AG (Germany) owns a chromite mine and is constructing a chromium chemical plant to produce chemicals from ore. Most ferrochromium producers own chromite mines or are owned by an entity that also owns such mines.

In Brazil, the mining and smelting of chromium is vertically integrated, but stainless steel production is independent of the mining-smelting operations. The major mining companies are subsidiaries of Cia. de Ferro-Ligas da Bahia S.A. Stainless steel is produced primarily by Companhia Acos Especiais Itabira. Other chromite operations in Brazil are also vertically integrated. For example, Bayer AG (Germany) owns a chromite mine and chromium chemical plant. Refractory chromite operations are also vertically integrated from chromite production through refractory material production. In China, the chromium industry is concentrated on ferrochromium production from imported ore. Only minor amounts of chromite ore and stainless steel are produced. A few major plants, as well as many small plants, produce ferrochromium or chromium chemicals. In Japan, chromite ore production is minor and primarily for use by the refractory industry. Ferrochromium production is significant but declining, while stainless steel production is significant. Some ferrochromium producers are associated with stainless steel plants by location, ownership, or both. Russia produces large quantities of ferrochromium and chromium metal and moderate quantities of chromite ore. In Kazakstan, chromite ore mining and ferrochromium production are vertically integrated. Russia produces large quantities of ferrochromium and chromium metal and moderate quantities of chromite ore. In Turkey, the chromium industry comprises large and small chromite ore producers, with one major producer, Etibank, integrated from mining through ferrochromium production. The chromium industry of Zimbabwe comprises large companies vertically integrated from chromite mine production through ferrochromium production, small

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independent chromite mines, and chromite mines operated independently on behalf of the large vertically integrated companies.

Capacity.—Rated capacity is defined as the maximum quantity of product that can be produced in a period of time at a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes plants that are operating and those that are temporarily closed, which, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Because not all countries or producers make production capacity information available, historical chromium trade data have been used to estimate production capacity. Variations in rated production capacity result from changes in facilities or in knowledge about facilities. Capacities have been rated for the chromite ore, ferrochromium, chromium chemical, and chromium metal industries. *(See table 18.)*

Reserves.—The United States has no chromite ore reserves. The United States, however, has a reserve base and resources that could be exploited. Domestic and foreign reserve estimates are reported by the USGS in other publications.

Production.—World chromite ore production was estimated to be about 12.2 million tons, a 15% reduction from that of 1995. World ferrochromium production was estimated to be about 4.06 million tons, an 8.9% reduction from that of 1995. *(See tables 16 and 17.)*

Albania.—A joint venture between Albania and Japan in 1995 resulted in the identification of chromite ore reserves in the Shebinik area. The project identified chromite ore deposits containing 3 million to 5 million tons of ore. Albania continued negotiations for a joint venture with foreign investors to develop its chromium industry. Albania and Preussag Stahl AG (Germany) negotiated a joint venture wherein Preussag would invest in Albania's chromite ore mining and ferrochromium-producing industries. The Federation of Miners, Geologists and Energy Workers and the Syndicate of Miners objected to privatizing the chromite mines. Negotiations will continue in 1997.

Australia.—Dragon Mining NL studied the feasibility of mining and processing chromiferous laterite resources at Range Well. The project involved the mining of 40,000 tons per year of ore from a 31-million-ton resource to produce 20,000 tons per year of 12% chrome-iron grinding media. Valiant Consolidated Limited formed a joint venture with Danelagh Resources Pty. Ltd. to mine chromite from the Coobina Deposit on a trial basis. Danelagh has smelted ore satisfactorily in China.

Brazil.—Cia. Ferroligas do Amapa reported expanding its chromite ore beneficiation plant capacity from 150,000 to 200,000 tons per year. Ferroligas also reported closing its smelter, which has been producing ferromanganese.

Canada.—Coleraine Mining Resources discontinued development of its chromite properties in the Thetford Mines area of Quebec Province. Coleraine had planned to produce chromite ore of 48% Cr_2O_3 at the rate of 20,000 tons per year from the Hall and the Montreal deposits, but the results of a feasibility study indicated that current reserves were inadequate for a profitable venture.

China.—China reported imports of chromite ore 769,147 tons, mostly from India, Iran, South Africa, and Turkey and record exports of ferrochromium at 122,115 tons, mostly to Japan, the Netherlands, and the Republic of Korea. China reported trade statistics for 1995 as follows: chromite ore imports of 1.38 million tons and exports, 3,975 tons; ferrochromium imports of 880 tons; exports, 320,950 tons; and chromium metal imports of 449 tons and exports, 10,577 tons. On the basis of these trade data and chromite ore production of 70,000 tons, China's chromium apparent consumption in 1995 was 240,000 tons of contained chromium.

Croatia.—Dalmacija Ferroalloy works reported shutting down in May.

Finland.—**Chromite Ore.**—Outokumpu Chrome Oy's (Outokumpu) Kemi Mine produces about 500,000 tons of chromite products (including metallurgical and foundry grade material) from about 1 million tons of run-of-mine ore extracted from surface operations. Kemi's proven and probable reserves were reported to have been 70.4 million tons graded at 26% chromic oxide. Outokumpu operated two (Elijarvi and Nuottijarvi) of three pits and planned to extend mining to underground.

Ferrochromium.—Outokumpu produces ferrochromium by a process optimized for the Kemi ore and subsequent stainless steel production. Chromite concentrate from Kemi is ground and pelletized with coke and bentonite in 10- to 15-millimeter-diameter pellets. The pellets are preheated and sintered by using carbon monoxide gas from the smelting process as a fuel. The hot-charged, sintered-pellet process permits Outokumpu greater chromium recovery and ferrochromium-production capacity, reduced energy consumption, and smoother arc furnace operation.

Stainless Steel.—Outokumpu Polarit, the stainless-steel-producing division of Outokumpu Oy, takes liquid and crushed ferrochromium from the Outokumpu Chrome Oy ferroalloy plant. A chrome converter furnace is used to combine liquid ferrochromium with stainless steel scrap before feeding the material to an argon-oxygen converter. Outokumpu Steel Oy increased its stainless steel slab production capacity to 540,000 tons and planned to increase its stainless steel slab production capacity to 1.2 million tons over a 10-year period.

France.—Delachaux invested more than 40 million francs in a new chromium metal factory at Valenciennes. In 1993, Delachaux moved its chromium metal production from Gennevilliers to Pau but, this year started renovation of a factory site in Valenciennes to house its chromium metal division. The Valenciennes plant was scheduled to start production in 1997. Delachaux planned to operate three vacuum degassing furnaces with a collective annual production capacity of about 4,500 tons per year. Market demand permitting, increased production

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could range from 6,000 to 7,000 tons per year.

Germany.—Bayer AG planned a joint venture with Sentrachem (South Africa) to produce sodium dichromate at Sentrachem's Karbochem plant, Newcastle, KwaZulu-Natal. The plan was for the South African plant to start up when the Leverkusen plant in Germany closes. (See South Africa section.) The new plant was planned to have a production capacity of 70,000 tons per year of sodium dichromate and 11,000 tons per year of chromic acid. South African chromite ore has been used for sodium dichromate production since before 1900. A major chromium chemicals plant has, however, never been built in South Africa because sodium dichromate production requires soda ash, which was not readily available in South Africa before 1991. Since 1900, the sodium dichromate production industry has been characterized by consolidation of suppliers and concentration of production capacity because chromium chemical demand has shown slow growth. As a result, opportunities to install new sodium dichromate production capacity have been few. Consequently, with the closing of Bayer's Leverkusen plant, an opportunity has arisen. In addition, soda ash is now available from Botswana Soda Ash (Botswana), and the Karbochem plant has underutilized industrial infrastructure. Also, Bayer mines chromite ore in South Africa and produces chromium chemicals from sodium dichromate. The new plant at Newcastle was estimated to have cost 150 million rands and will use an improved production process. Chemical production cost was estimated to be divided nearly equally among the costs of chromite ore, soda ash, energy, and other. The Newcastle plant will use less than the international average of 1.5 units of soda ash per unit of chromite ore by roasting ore in an oxygen-rich atmosphere and recycling sodium units. The Newcastle process also uses carbon dioxide instead of sulfuric acid, thereby improving reaction yield of sodium dichromate. Because carbon dioxide will be used, sodium sulfate will not be a byproduct, and caustic soda will be generated as a byproduct of chromic acid production by electrolysis of sodium dichromate. Process gasses were to be used, thus improving energy efficiency. Residual hexavalent chromium was to be converted to trivalent chromium.

India.—India resolved a dispute over access to chromite ore reserves in Orissa State. Tata Iron and Steel Co. Ltd. sought to renew its chromite ore mining lease covering 1,261 hectares of land in Sukinda Valley in 1992 after holding that lease for 20 years. The High Court of Orissa State awarded 406 hectares to Tata and ruled that the remaining 855 hectares were to be divided among Ferro Alloys Corp. Ltd., Jindal Ferro Alloys Ltd., Indian Metals & Ferroalloys, and Ispat Alloys Ltd. Tata was expected to continue to produce at the annual rate of 750,000 tons of chromite ore and 150,00 tons of chromite concentrate.

India imposed antidumping duties on low-carbon ferrochromium from Russia and Kazakstan. Average annual production of low-carbon ferrochromium by Ferro Alloys Corp. Ltd. and Industrial Development Corp. dropped from about 12,000 tons in 1993 to about 4,500 tons 1995 as import duties fell from 80% to 40% then to 30%. The tariff on Kazakstani material was set at 18,500 Rupees; Russian material, from 10,900 to 18,600 Rupees.

Power rates continue to rise in Madhya Pradesh, Andhra Pradesh, Karnataka, Maharashtra, and Orissa States. National Thermal Power Corp. supplied power at rates lower than those of the national grid.

Ferrochromium.—Indian Charge Chrome Ltd. closed its Choudwar, Orissa, ferrochromium and electrical powerplants after sustaining about $2.79 million worth of damage resulting from a worker-management disagreement over wages and tenure issues.

Ispat Alloys Ltd. operated four furnaces (two rated at 15 megavolt-amperes and two at 7.5 megavolt-amperes), two of which were used to produce high-carbon ferrochromium at a rate of about 36,000 tons per year. Ispat's plant is located at Balgopalpur, Balasore, Orissa. It is adjacent to National Highway 6 and connected to the railway. Ispat obtains chromite ore from Orissa Mining Corp. Ltd. and Mysore Mineral Ltd., which are in Sukinda Valley about 160 kilometers from the plant. Ispat exports through Paradip or Calcutta, which are about 250 kilometers from the plant.

Jindal Ferro Alloy Ltd. operated ferrochromium plants at Vizag and Raigad, Madhya Pradesh, with a production capacity of 30,000 tons per year each. The Vizag plant was producing at a rate of 20,000 tons per year, whereas the Raigad plant closed. Both plants were expected to operate at higher capacities when a new stainless steel expansion begins production. Jindal expected to produce chromite ore in Orissa once legal barriers to its getting a lease are cleared.

Stainless Steel.—India's stainless steel production was estimated to be more than 500,000 tons. Jindal planned to increase capacity at its Hissar, Haryana, plant to about 200,000 tons. Upon completion of this project, India's annual stainless steel production capacity will be about 1 million tons. Sail's Alloy Steel Plant at Dugapur, West Bengal, planned to increase its stainless steel production capacity to about 105,000 tons per year in 2000, and Salem Steel Plant was studying the feasibility of introducing stainless steel production.

Indonesia.—Krakatau Steel and Krupp Thyssen Nirosta planned a joint venture to produce stainless steel at Krakatau's plant by adding an argon-oxygen decarburization converter. Krakatau planned to expand its stainless steel production capacity to 50,000 tons per year by the end of 1997 and ultimately to 250,000 tons per year.

Iran.—Iran produced chromite ore from three mines (Faryab, Esfandagheh, and Foroumad) and ferrochromium from one smelter at Roudan.

Japan.—Japan imported 686,451 tons of chromite ore, 718,567 tons of ferrochromium, 1,916 tons of chromium metal, and 165,153 tons of stainless steel scrap. Domestically, the ferroalloy industry produced 211,053 tons of ferrochromium, a decrease of 11% compared with that of 1995. (Between 1980 and 1996, the ferrochromium production has ranged from about 211,000 to 360,000 tons per year with the lower limit set in 1996.) Hot rolled stainless steel production was reported to be 3.23 million tons a decrease less than 1% compared with that of

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1995. Ferrochromium imports represented 77% of market share. Japan exported 1,191 tons of ferrochromium and 1.15 million tons of stainless steel, representing 36% of production. Japan's ferrochromium industry loss of market share in 1996 is consistent with the world trend to rationalize ferrochromium production in countries that consume ferrochromium in favor of expansions in countries that produce chromite ore. On the basis of chromite ore, ferrochromium, and chromium metal trade, chromium apparent consumption in Japan was 602,408 tons contained chromium. At yearend, ferrochromium stocks at steel plants totaled 157,642 tons—149,642 tons of high-carbon (2.27 months of supply) and 7,502 tons of low-carbon ferrochromium (1.87 months of supply).

Ferrochromium.—Japan continued to buy into foreign ferrochromium operations as it rationalized its domestic ferrochromium industry. In 1993, Tubatse Ferrochrome Division (Samancor Ltd., South Africa) and Nippon Denko Co. Ltd. formed NST Ferrochrome to produce high-carbon ferrochromium. In 1995, two new joint ventures were formed between Japanese and South African companies for the production of ferrochromium in South Africa. Mitsui and Co. bought a share of Lydenburg ferrochromium plant [Consolidated Metallurgical Industries Ltd. (CMI), South Africa] to get a share of its high-carbon ferrochromium production. Mitsui carried out its acquisition via its newly formed wholly owned subsidiary in South Africa, Mitsui Minerals Development of South Africa Pty. Ltd. Mitsui chose this method instead of a joint venture, possibly positioning itself for further investments in the South African minerals industry. Showa Denko K. K. and Marubeni Corp. formed Technochrome, a joint venture with Middelburg Ferrochrome Pty. Ltd. (Samancor Ltd., South Africa), to produce low-carbon ferrochromium in South Africa. In addition to investments in South Africa, Japan invested in Zimbabwe. Japan Metals and Chemicals (JMC) and Mitsui and Company established a joint venture with Zimbabwe Alloys Ltd. to use an idle furnace for the production of low-carbon ferrochromium in Zimbabwe. Low-carbon ferrochromium production in Zimbabwe was expected eventually to displace JMC's low-carbon ferrochromium production at its Oguni plant. (See Zimbabwe section.)

JMC restricted electric furnace operation to take advantage of the lower electrical energy cost during low-demand time periods at its Kyushu plant. As a result, annual production was expected drop from 73,000 to 40,000 tons.

Stainless Steel.—Kawasaki Steel, Chiba Steel Works, and NKK Corp., Fukuyama Works, continued to test stainless steel production by using chromite ore directly, thus displacing the necessity of getting chromium units from ferrochromium. Kawasaki acquired high-chromic oxide chromite ore from India and low-chromic oxide byproduct from platinum production in South Africa.

Kazakstan.—Japan Chrome Corp. (JCC), the management organization that took control of Kazakstan's ferrochromium industry under a 5-year contract through Kazchrome, started reorganizing the industry to improve service, reliability, and supply and to reduce cost. The industry comprises Donskoy Mine, Aktubinsk Ferroalloy Works, and Aksu Ferroalloy plant. Trans-World Group, a trading company that is the selling agent for JCC, is a major share holder of JCC and has other interests in Kazakstan. Under JCC management, crushing and sizing equipment has been introduced, product chemical specifications have been modified to meet user requirements, and a new ferrochromium furnace was installed. To stabilize electrical energy supply, JCC invested in an electrical power plant. Electrical power for Aksu is secure; Aktubinsk, however, faced reduced electrical energy supply. JCC reorganized plant product mixes to assure the low cost of production and the availability of product. Aksu was targeted for high-carbon ferrochromium production, while Aktubinsk was to produce medium- and low-carbon ferrochromium and ferrochromium-silicon. Aksu 1 works was to produce manganese ferroalloys. Aksu 2 works was to produce ferrochromium from eight electric furnaces (four rated at 16.5 megavolt-amperes and four at 21 megavolt-amperes) with production capacity of 330,000 tons per year. The No. 4 works produced ferrochromiumsilicon with a capacity of 70,000 to 80,000 tons per year.

Korea, Republic of.—The Republic of Korea reported imports of ferrochromium to have been 180,161 tons, a 9% increase over that of 1995. Pohang Iron and Steel Company installed new stainless steel production equipment, raising its production capacity to 820,000 tons per year.

Norway.—Low rainfall and the subsequent shortage of electrical energy caused Elkem A/S to purchase electrical energy on the spot market. Higher energy costs, the necessity for equipment maintenance, and weak demand caused the to closure of its furnaces at yearend.

Philippines.—Three private mines, Loreto Mining Corp., Chrominco, and Naradeco, were reported operating. Loreto mined chromite from the Kongking ore body. Loreto had reserves that range from 150,000 to 200,000 tons of 48% to 52% Cr_2O_3 lumpy ore. Adequate rainfall made hydroelectric power available. Increased electrical energy cost, however, made ferrochromium production noncompetitive at world ferrochromium prices.

Russia.—Russia reported 1995 ferrochromium trade to have been as follows: high-carbon ferrochromium exports, 166,822 tons, and imports, 11,607 tons, and low-carbon ferrochromium exports, 98,551 tons, and imports, 7,492 tons.

Chromite Ore.—B&D Industrial Group B.V. (Netherlands) (B&D) developed the Agonoziorski Chrome Mine, near Pudovski, Karelia Region. The mine's proven reserves were 85 million tons graded about 30% Cr_2O_3; reserves were estimated to be 700 million tons. The mine was to supply chromite ore to B&D's Tikhvin ferrochromium plant, about 250 kilometers away by railroad. Rights to develop a chromite deposit in the Yamal Peninsula, Yamalia, were awarded to Polar Mining & Prospecting, a local company. The deposit was thought to have reserves of 50 million tons.

Ferrochromium.—B&D, a Dutch incorporated holding company, started construction of Northeast Ferro Alloy Works, a new ferrochromium plant at Tikhvin. Northeast was owned by

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B&D (68%), Transmash Heavy Machine Building Works (25%), and AOZT VAO High Speed Railroad (7%). The plant will comprise four 16.5-megavolt-ampere furnaces with combined production capacity of 170,000 tons per year. Production from two furnaces was planned to start in the second quarter of 1997, followed by the remaining two furnaces in the third quarter.

The Serovsk Ferroalloy Works and the Chelyabinsk Electrometallurgical Works were forced to reduce production, because of high electrical energy cost and lack of raw materials supply, respectively. Chelyabinsk supplemented its chromite ore supply from Kazakstan with chromite ore from Turkey and from Verkhny Ufalei Mining Combine, a local producer.

Chromium Metal.—Klyuchevsk Ferroalloy Works reported aluminothermic production ranging from about 1,800 to 2,400 tons per year. Klyuchevsk planned to produce low-carbon ferrochromium.

Slovenia.—Tovarna Dusika Ruse Metalurgija d.o.o. produced high-carbon ferrochromium with a capacity of 15,000 tons per year and low-carbon ferrochromium a with capacity in the range of 3,300 to 3,400 tons per year.

South Africa, Republic of.—The South African Minerals Bureau reported chromium industry performance for 1995. Chromite ore production was 5.086 million tons from a reserves base of 3.1 billion tons and a production capacity of 2.4 million tons distributed among 20 mines. Exports accounted for 25% of production. Ferrochromium production was 1.386 million tons, of which 37% was exported.

Chromite Ore.—Anglovaal Ltd. operated its newly opened Ntuan Mine about 40 kilometers west of Sun City in North-West Province. Run-of-mine production was 120,000 tons per year from reserves of 6.6 million tons in the LG6 seam and 2.5 million tons in the MG4 seam. Anglovaal supplies its Feralloys smelter and exports chromite ore. B&D purchased Buffelsfontein Mine from National Manganese. The mine was producing at 150,000 tons per year from reserves of 37 million tons. B&D planned to build a 140,000-ton-per-year smelter at the mine.

Consolidated Metallurgical Industries (CMI) purchased mineral rights to Thorncliffe Farm in Northern Province from Johannesburg Consolidated Investment Ltd. for 64.8 million rands. The mine had reserves of 27 million tons down to 300 meters. CMI started surface mining at Thorncliffe and planned to develop the mine by adding underground operations and upgrading beneficiation facilities. CMI planned Thorncliffe to have a chromite production capacity of 1 million tons per year by 1999 and 2 million tons per year by 2001. Thorncliffe production will displace material formerly purchased from Samancor. CMI worked on constructing a highwall in preparation for driving shafts while performing surface mining. CMI was investigating the adjacent Helena farm, which has reserves of 100 million tons.

Chrome Resources (Pty.) Ltd (Chrome Resources) opened a new mine at Wonderkop covering 1,700 hectares to feed its smelter at that location. Wonderkop Mine was designed to produce about 60,000 tons per month run-of-mine from the LG6 seam, which is about 1.4 meters thick and inclines at 12 degrees. Run-of-mine ore production is transported by conveyor to the beneficiation plant with output of from 32,000 to 36,000 tons per month of marketable product. The marketable chromite ore is 44% to 46% Cr_2O_3 with 1.5 Cr:Fe. Wonderkop uses a room-and-pillar mining method from three inclined shafts of from 380 to 450 meters in length and going to a depth of from 80 to 90 meters. The mine uses 12- by 6-meter pillars spaced 10 meters in one direction and 4 meters in the other to recover 72% of in situ material. Chrome Resources continued mining at the Waterval (30,000 tons per month run-of-mine) and Kroondal (70,000 tons per month run-of-mine) sections near Rustenburg. Chrome Resources reported production of 1.2 million tons from these sections in 1995.

Northern Province Development Corp negotiated a joint venture with East Asian Metal Investment which was to include the Dilokong Mine and a proposed ferrochromium smelter at or near the mine site.

Ferrochromium.—The South African ferrochromium industry is dynamic and innovative. Vertical integration of the chromium industry has resulted in the expansion and planned expansion of ferrochromium production in South Africa by using abundant supplies of domestic chromite ore and coal-based electrical energy. Japan continued to buy into the South African ferrochromium industry, this year joined by China and the Republic of Korea. South Africa's ferrochromium industry was expanding to meet a world demand driven by a growing stainless steel market and a local demand driven by recently installed or expanded stainless steel production facilities. Expansions and/or new plants added six furnaces comprising 239 megavolt-amperes in electrical energy capacity and 415,000 tons per year ferrochromium production capacity. These additions to South Africa's ferrochromium production capacity are about 30% of 1995 capacity. In addition to production capacity resulting from the installation of new furnaces, South Africa increased its ferrochromium production capacity through improvements in the production process; for example, briquetting furnace-feed materials and ferrochromium from slag recovery.

Feralloys, an Anglovaal subsidiary, reported production of high-carbon ferrochromium from its three 24-megavolt-ampere furnaces at Machadodorp, KwaZulu-Natal Province. Feralloys installed a ferrochromium-from-slag recovery process.

Hernic Ferrochrome (Pty.) Ltd. (Hernic) commissioned a new ferrochromium plant near Brits with two 37-megavolt-ampere furnaces of combined production capacity in the range of 130,000 to 140,000 tons per year. One furnace was built by Titaco, the other by Elkem. Hernic reported its production cost to have ranged from $0.27 to $0.32 per pound. Hernic planned a $53 million pelletizing plant, which would reduce production cost by $0.01 per pound and double production capacity. Hernic is privately owned by Wilfried Pabst, Herman Van Rooyen, ELG Haniel (Germany), and Nittetsu Shoji (Nippon Steel, Japan).

CMI operated ferrochromium plants at Rustenburg, North-West Province, and Lydenburg, Mpumlanga Province.

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Rustenburg capacity was 120,000 tons. A fourth furnace was commissioned at Lydenburg increasing its production to 310,000 tons per year. Unlike the other three furnaces, the new one does not require solid-state reduction of the chromite ore feed. The new furnace had an electrical energy capacity of 39 megavolt-amperes and was planned to have a production capacity of 70,000 tons per year. CMI operated the Purity Mine near its Rustenburg smelter and the Thorncliffe Mine near its Lydenburg smelter.

At Wonderkop Mine, Chrome Resources constructed a smelter consisting of two furnaces with electrical capacity of 44 megavolt-amperes and ferrochromium production capacity of 160,000 tons per year; two more furnaces are planned in 1997. The smelter includes a pelletizing plant and can use byproduct UG2 chromite ore from nearby platinum mining operations. The smelter produces charge grade ferrochromium (52% to 55% chromium) and uses up to 18% of chromite ore feedstock in the form of UG2 seam chromite ore byproduct from platinum mining. The UG2 material is 41% Cr_2O_3 with 1.4 Cr:Fe, from which, by itself, ferrochromium of 47% to 48% chromium, a nonstandard grade, would be produced.

At Ferrometals Division, Samancor formed Poschrome under a joint-venture agreement with Postrade (a subsidiary of Posco Iron and Steel, Republic of Korea) and Samsun (Republic of Korea) to Samancor contributes 50% to the projects assets, and the others, 25% each. The joint venture was to upgrade the Ferrometals No. 6 furnace by adding pelletizing, sintering, and preheating facilities at a cost of $40 million. Under a joint-venture agreement with NSA Metals in which Samancor holds 51%, Samancor formed Crometals (Pty.) Ltd., to upgrade furnace No. 5 at Ferrometals by adding pelletizing, sintering, and preheating facilities, increasing furnace production capacity by 15,000 tons per year. NSA Metals is an investment firm owned 55% by Nisshin Steel (Japan) and 45% by Nissho Iwai (Japan). Samancor contracted with Outokumpu Engineering Contractors Oy to provide the pelletizing and sintering plant and the preheating shaft kilns at a cost of $24 million. The pelletizing plant was to have a production capacity of 520,000 tons per year and to be completed in 1997. The preheating shaft kiln was to be completed in 1998.

At Tubatse, Samancor added a sixth furnace and a ferrochromium-from-slag recovery plant at its plant. The new furnace had electrical capacity of 37 megavolt-amperes and increased ferrochromium production capacity by 55,000 tons per year at a cost of 92 million rands. The ferrochromium-from-slag recovery plant increased ferrochromium production capacity by 20,000 tons per year at a cost of 23 million rands.

At Middelburg, Samancor commissioned a plasma-arc furnace for use with the chromite direct reduction process. The kiln used for direct reduction was to be completed in 1997.

Stainless Steel.—Columbus Joint Venture and ISCOR Limited developed their stainless steel production facilities. Columbus completed its plant in 1995 and optimized its operations in 1996; production was estimated to be 250,000 tons. The company planned to reach production of 400,000 tons per year in 1997 from a capacity of 500,000 tons per year. ISCOR proceeded to convert its Pretoria and Durban steel plants to stainless steel production. The Pretoria works was designed to produce stainless steel slab from liquid iron, with a capacity of 480,000 tons per year. The Durban Works was designed to produce billets and ingots from steel scrap, with a capacity of 100,000 tons per year.

Chemicals.—Bayer AG (Germany) entered a joint venture with Sentrachem to produce sodium dichromate and chromic acid at Newcastle, KwaZulu-Natal Province. The new facilities were to be built at Sentrachem's currently active Karbochem plant site in Newcastle at a cost of $114 million shared equally between the joint-venture partners. The plant was planned to start production in 1998 with a production capacity of 70,000 tons per year of sodium dichromate and 10,000 tons per year of chromic acid. The major feed materials, chromite ore and soda ash, were to come from Bayer's Rustenburg Chrome Mine near Rustenburg, North-West Province, and Botswana, respectively. Typical ratio of soda ash to chromite ore in the production of sodium dichromate is 1.5:1. The new plant is designed to reduce this ratio. Other design features of the new plant include maximization of energy efficiency by using process gases, reduction of waste residue by maximizing reaction yields, conversion of residual hexavalent chromium to trivalent, and soda ash recovery by converting sodium monochromate to dichromate by carbon dioxide acidification. Carbon dioxide replaces the commonly used sulfuric acid in the acidification process, thereby avoiding the production of hexavalent chromium contaminated sodium sulfate. Chromic acid was to be produced from sodium dichromate by electrolysis, which would result in a caustic soda byproduct that would be recovered and reused. Bayer already produces chromium tanning compounds from sodium dichromate in South Africa at its Merebank plant in Durban, KwaZulu-Natal Province. Most (80% to 90%) of the new plant's chemical compounds are destined for export through Durban.

Spain.—Acerinox reported operating a second argon-oxygen-decarburization converter, which was installed in 1995, and modernizing their original converter, thus increasing its hot metal production capacity from 721,000 to 831,000 tons per year.

Taiwan.—Taiwan reported imports of 186,637 tons of ferrochromium to supply its stainless steel producers and exports of 48,237 tons of stainless steel scrap. Major primary stainless steel producers include Yieh United, Tang Eng, and Walsin-Car Tech.

Turkey.—Etibank reported that it was considering changes to chromium operations. Included were the possibility of privatizing chromite mines and ferrochromium smelters, and the possible construction of a stainless steel plant at Elazig, the location of its high-carbon ferrochromium plant.

United Kingdom.—British Chrome & Chemicals Ltd. (BCC) started construction of a new chromic acid plant, which cost as much as $18 million at its Eaglescliffe site, with production capacity of 25,000 tons per year. The new plant is a joint venture with Nippon Denko Co. Ltd. (Japan). The new plant was expected to start production in 1998 at which time the

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old plant, with production capacity of 13,000 tons per year, was to be shut down. BCC's new plant was expected to produce 3- to 4-millimeter chromic acid crystals; acid is used in metal finishing, plating, and wood preservation.

BCC is the only Western producer of chromic oxide for aluminothermic chromium metal production. In the United Kingdom, cost of production rose as a result of increased costs of soda ash and ammonium sulfate and the United Kingdom landfill tax. As a result of these added costs, BCC raised the price of aluminothermic chromium metal-grade chromic oxide by 20%.

London & Scandinavian Metallurgical Co. Ltd. planned a new chromium metal plant at its Rotherham site. This new chromium metal plant was expected to come into production in 1997, at which time the old plant was to be shut down. The new plant was to have a production capacity in the range of 3,600 to 4,800 tons per year compared with current production capacity of 3,000 to 4,000 tons per year.

Zimbabwe.—Zimbabwe suspended exports of chromite ore after permitting such exports a year ago.

Chromite ore.—Zimbabwe Alloys Ltd. reported 1995 mine production, in tons, as follows: Great Dyke Mine, 9,471; Great Dyke Outcrop, 6,108; Inyala Mine, 4,545; north Dyke co-operatives, 57,051. Other sources supplied 85,346 tons putting Zimbabwe alloys receipts at 162,514 tons (The TEX Report, 1996). Zimbabwe Alloys reported 1995 production of 29,594 tons of low-carbon ferrochromium and 42,284 tons of ferrochromiumsilicon. At the Great Dyke Mine, Zimbabwe Alloys extended the shaft to greater depth. At its Inyala and Sutton Mines, Zimbabwe Alloys explored the deposits in preparation for deepening the shafts and commissioned a heavy media separation plant.

Ferrochromium.—Zimbabwe Mining and Smelting Co. Ltd. reported production of 213,000 tons per year (190,000 tons per year from furnaces, 23,000 tons per year recovery from slag), compared with production of 218,000 tons in 1995.

Zimbabwe Alloys signed a joint venture agreement with JMC and Mitsui to produce low-carbon ferrochromium. The joint venture, to be called JM Alloys (Private) Ltd., is intended to supply low-carbon ferrochromium to Japanese consumers, replacing that produced by JMC as it closes down its Oguni plant in Japan. JMC and Mitsui each have a 25% share. Technology transfer from JMC to Zimbabwe Alloys was expected to raise low-carbon ferrochromium production capacity by 5,000 tons per year. Among the technological improvements to raise productivity are preheating of chromite ore feed and other changes to the material flow processes.

Current Research and Technology

Mineral Processing and Industrial Applications.—Research on the recovery of chromium from low-grade chromite concentrate by a low-temperature soda-roasting method found that chromite ore from the Mouat Mine, Stillwater Complex, Montana, is not amenable to traditional chemical processing (roasting at high temperature with soda ash) owing to its silicon content (Chandra and others, 1996). Bubbling oxygen and tumbling during roasting were reported to improve an alternate method (roasting at low temperature with sodium hydroxide) of chemical processing. This research was conducted by the former U.S. Bureau of Mines in support of the Strategic and Critical Materials Stock Piling Act of 1946, as amended; the Defense Production Act of 1950, as amended; the Mining and Minerals Policy Act of 1970; and the National Materials and Minerals Policy, Research and Development Act of 1980.

The Council for Mineral Technology (Mintek) of the Republic of South Africa conducts government and commercially sponsored and cosponsored research and development on chromite ore and ferrochromium. Recent Mintek research has included chromite beneficiation, agglomeration, smelting, chromium recovery from slag, and stainless steel alloying. Ferrochromium-from-slag recovery by using a hydropneumatic coarse jigging process is being implemented in Southern Africa. The process developed jointly by Mintek and Titaco recovers more than 95% of chromium contained in slag with less than 2.5% of slag in the product. Processing plants with slag processing capacity in the range of 100 to 200 tons per hour have been built. The process contains (that is, prevents dispersal of) the material being processed while it is processed, recovers metal values in usable form, and results in a more environmentally acceptable slag byproduct (Mining Weekly, 1996).

Sermatech reported the results of a high-velocity thermal spray process that used chromium carbide to repair worn Tennessee Valley Authority power-generation equipment (Sielski and Sahoo, 1997). Chromium carbide has a thermal expansion coefficient near that of iron and nickel, the major constituents of base materials subject to solid-particle erosion. The coating was demonstrated to be an economic alternative to upgrading the base material in some applications.

Environmental.—Environmental concerns about chromium have resulted in a wide variety of studies to determine chemical characteristics, natural background levels, sources of environmental emissions, movement of chromium in the environment, interaction of chromium with plants and animals, effect of chromium on plants and animals, measurement methods, and recovery technology.

A new electrode suited to electrokinetic remediation of soils (chromium removal) not saturated with water is being investigated at Sandia National Laboratories (Mouché, 1996). Sandia is testing the technique by using four electrodes to remediate a chromic acid pit measuring 18 feet by 45 feet. Electrodes cost about $12,000 each, but their use does not require digging up the site.

Outlook

On average (from 1983 through 1992), U.S. chromium consumption, by end-use industry, has been: metallurgical, 87%; chemical, 10%; and refractory, 3% (Papp, 1994). About 70% of metallurgical industry chromium consumption is as feed

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material for stainless steel production. Thus, stainless steel production accounts for about 60% of the chromium consumed in the United States. The remainder of metallurgical industry consumption is for the production of other ferrous and nonferrous alloys. Some chemical and refractory products are consumed in steel production. The average chromium content of stainless steel produced in the United States from 1962 through 1983 was 17% (Papp, 1991). Stainless steel, by definition, contains at least 11% chromium but may contain as much as 36% is chromium.

In 1989, it was estimated that, on average internationally, the metallurgical industry consumed about 79% of chromium; the chemical industry, 13%; and the refractory industry, 8% (Granville and Statham, 1989). Of the chromium consumed in the metallurgical industry, about 60% was consumed in stainless steel. Thus, stainless steel production accounted for about 50% of the chromium consumed internationally. In 1993, it was estimated that, on average internationally within market economy countries, the metallurgical industry consumed about 77% chromium; the chemical industry, 14%; and the refractory industry (including foundry sand), 9% (Boyle and others, 1993). A comparison of world production of chromite ore, ferrochromium, and stainless steel as reported in contained chromium in table 1 shows that, on average, from 1992 through 1996, chromium contained in ferrochromium was about 79% of chromium contained in ore production and about 87% of that in stainless steel.

The outlook for chromium consumption in the United States and internationally is about the same as that for stainless steel, which is the major end use for chromium worldwide. Thus, stainless steel industry performance largely determines chromium industry demand worldwide.

The trend to supply chromium in the form of ferrochromium by chromite mining countries is expected to continue. With new, efficient ferrochromium production facilities and excess capacity in chromite-producing countries, production and capacity are expected to diminish in traditional nonore-, but ferrochromium-producing countries. Production by small, less efficient producers, except where domestic industries are protected by quotas and tariffs is also expected to decline. Further upward integration of the chromium industry is expected as countries that produce chromite expand ferrochromium or stainless steel production capacity.

China has emerged as a potential major factor in the world chromium market. Because China produced only a minor amount of chromite ore, it is primarily a processor and consumer of chromium and supplies substantial quantities of ferrochromium and chromium metal to world markets. Continued industrial growth in China could result in increased demand for stainless steel there because its use is characteristic of the larger and more technologically developed economies.

Ferrochromium.—Ferrochromium production is electrical energy intensive. Charge-grade ferrochromium requires from 3,800 to 4,100 kilowatt-hours per ton of product, with efficiency varying with ore grade, operating conditions, and production process. Thus, ferrochromium plant location reflects a cost balance between raw materials and electrical energy supply. The South African share of ferrochromium production increased to 48% from about 35% in 1992. It was expected of exceed 50% in 1997.

Stainless Steel.—Analysis of the stainless steel industry based on historical performance and announced production capacity increases indicated that from 1982 to 1995, world annual stainless steel production grew from 7.5 to 15 million tons, an annual growth rate of 5.5%. Annual demand reportedly grew even faster. Planned expansions in nine countries (Brazil, China, India, Indonesia, Malaysia, the Republic of Korea, South Africa, Taiwan, and Thailand) were expected to add 4 million tons of crude stainless steel production capacity (3.66 million tons, rolled product) by 2000 (Mole and Armitage, 1996).

Western stainless steel production showed double-digit percentage growth in 1994 and 1995. In 1995, strong demand for stainless steel resulted in excessive production, which resulted in large stocks of stainless steel in 1996. At the same time, capacity expansion projects already under way continued to come into production. From 1994 through 1996, an estimated 3.865 million tons of stainless steel production capacity was added. Excess stocks forced prices and production down. Reported prices declined by 45% from peak prices in 1995, while production declined by as much as 5%.

Price for stainless steel is demand sensitive, and an important part of it is the cost of nickel (about 70% of stainless steel requires nickel). Nickel availability and cost have been viewed as potential limitations to increased stainless steel production. The discovery and development of new nickel deposits projected to produce at nearly one-half the cost of that of current deposits mitigate this potential limitation to stainless steel production growth.

Chromium Chemicals.—Chromium chemical production is geographically concentrated in developed economies. Major producing countries where large plants (capacity in excess of 100,000 tons per year of sodium dichromate) operate include Kazakstan, Russia, the United Kingdom, and the United States. Moderate-sized production facilities are located in Brazil, China, Germany, Japan, Romania, and Turkey. Moderate-scale plant development to displace production in Germany is underway in South Africa. Small-scale local producers operate in China and India.

Sodium dichromate apparent consumption in 1994 was estimated to be 110,000 tons in the United States, 137,000 tons in Western Europe, and 42,000 tons in Japan (Will, Leder, and Mori, 1996). In the United States, most sodium dichromate is converted to chromic acid; some, however, is used directly by several industries. Major enduse markets for sodium dichromate— wood preservation, leather tanning, and metal finishing—are mature markets showing slow growth. Other enduses showing declining use include chromate pigments, corrosion control agents, and water-treatment chemicals. Newer, faster growing markets include magnetic recording media and catalysts and represent a small part of the market. In Europe, leather tanning was a major enduse. In Japan, electroplating and metal finishing were major enduses.

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The domestic chemical industry has restructured over the years. In 1951, demand distribution among major enduses was leather tanning and metal finishing, 25% each, and pigments, 35%. Today, demand distribution among major enduses is: wood preservation, 42%; metal finishing, 14%; pigments, 13%; and leather tanning, 9%. Sales during the time period were estimated to have grown by 20%. Demand is expected to continue the same slow growth rate (Barnhart, 1977). In 1996, the enduses of sodium dichromate were estimated to have been chromic acid, 64%; leather tanning, 12%; chromic oxide, 10%; chrome pigments, 5%; wood preservative, 3%; miscellaneous, 6% (Mannsville Chemical Products Corp., 1997).

Chromium Metal.—Tosoh, the Japanese electrolytic chromium metal producer, ceased production in 1995, leading to an anticipated restructuring of the chromium metal industry. It was not until December 1996 that the company finally sold off its stocks. To a degree, Tosoh stocks have become consumer stocks. Restructuring of the chromium metal supply market will start in earnest in 1997, with the remaining electrolytic producers (Russia and the United States) competing with the major aluminothermic producers (France and the United Kingdom) for the Japanese market. Both aluminothermic producers are in a position to expand production. The price of chromium metal was expected to increase as raw material (chromic oxide) price increases are passed on to metal consumers. The price of low-grade chromium metal relative to ferrochromium in Japan permitted stainless steel producers to substitute chromium metal for ferrochromium. This substitution is expected to be curtailed as metal prices increase.

Chromite Foundry Sand.—At last count, about 3,100 foundries were active in the United States. These foundries tend to be small, independent operations. Chromite sand found a place in the casting industry in the 1960's when it substituted for zircon sand, which was in short supply. Since then, chromite sand has gained recognition as being technically suited to manganese steel and stainless steel casting because it produces a finish superior to that of zircon sand. Performance of the foundry industry is tied to that of the general economy, which has been strong and is expected to so continue. The automotive industry is a major demand sector for castings. Demand was good, stable, and expected to grow moderately. The use of nonmetallic materials could displace demand for metallic castings in the long term (Bolger, 1996).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT CHROMIUM STATISTICS 1/

(Metric tons, contained chromium unless otherwise specified)

		1992	1993	1994	1995	1996
World production:						
Chromite ore (mine) 2/		3,350,000 r/	2,880,000 r/	3,050,000 r/	4,320,000 r/	3,690,000 e/
Ferrochromium (smelter) 3/		1,990,000 r/	1,800,000 r/	1,940,000 r/	2,460,000 r/	2,240,000 e/
Stainless steel 4/		2,180,000 r/	2,150,000 r/	2,350,000 r/	2,660,000 r/	2,650,000 e/
U.S. supply:						
Components of U.S. supply:						
Domestic mines		--	--	--	--	--
Secondary		102,000	92,000	99,000	112,000 r/	98,400
Imports:						
Chromite ore		67,700	84,300	59,600	81,400	79,200
Chromium chemicals		4,320	6,210	9,210	8,360	7,060
Chromium ferroalloys		247,000	233,000	198,000	319,000	267,000
Chromium metal		5,450	6,170	6,520	7,040	8,730
Stocks, Jan. 1:						
Government		1,250,000	1,280,000	1,210,000	1,170,000	1,120,000
Industry		117,000 r/	118,000	103,000	101,000	80,100
Total U.S. supply		1,800,000	1,820,000	1,690,000	1,790,000	1,660,000
Distribution of U.S. supply:						
Exports:						
Chromite ore		2,180	3,310	14,000	5,740	21,900
Chromium chemicals		9,210 r/	8,170	11,700	14,700	18,200
Chromium ferroalloys and metal		6,530	9,420	7,600	6,260	10,800
Stocks, Dec. 31:						
Government		1,280,000	1,210,000	1,170,000	1,120,000	1,060,000
Industry		118,000	103,000	101,000	80,400	74,300
Total U.S. distribution		1,420,000	1,340,000	1,300,000	1,230,000	1,180,000
Apparent industry demand		378,000	484,000	390,000	566,000	480,000
Reported consumption (gross weight):						
Chromite ore		362,000	337,000	322,000	351,000	282,000
Chromium ferroalloys		367,000	357,000	346,000	334,000	328,000
Chromium metal		3,820	4,060	3,960	4,600	4,620
Stocks, Dec. 31 (gross weight):						
Government						
Chromite ore		1,850,000	1,640,000	1,470,000	1,320,000	1,170,000
Chromium ferroalloys		1,090,000	1,080,000	1,080,000	1,070,000	1,040,000
Chromium metal		6,150	7,060	7,690	7,690	7,720
Industry, producer		5,720	5,610	8,070	8,430	6,450
Industry, consumer:						
Chromite ore		321,000	275,000	266,000	205,000	173,000
Chromium ferroalloys		17,200	16,000	14,700	22,500	27,300
Chromium metal		438	481	292	264	211
Industrial releases and transfers: 5/						
Released		11,600	11,300	10,500	10,500	NA
Transferred		55,300	69,600	77,000 r/	69,300	NA
Total		66,900	80,900	87,500 r/	79,700	NA
Prices, average annual:						
Chromite ore, 6/ $/ton gross weight		51	55	55	60	75
Ferrochromium, 7/ $/lb chromium content		0.46	0.37	0.37	0.70	0.51
Chromium metal, 8/ $/lb gross weight		3.70	3.70	3.70	3.97	4.15
Value of trade:						
Exports	thousands	$56,200	$64,900	$69,900	$83,200	$111,000
Imports	do.	$330,000	$279,000	$254,000	$545,000	$463,000
Net trade 9/	do.	($274,000)	($214,000)	($184,000)	($461,000)	($352,000)

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Calculated assuming chromite ore to average 44% Cr2O3 that is 68.42% chromium.

3/ Calculated assuming chromium content of ferrochromium to average 57%.

4/ Calculated assuming chromium content of stainless steel to average 17%.

5/ Data on industrial releases and transfers from Environmental Protection Agency, Toxic Release Inventory (July 1997.)

6/ Time average price of South African chromite ore as reported by Platt's Metals Week.

7/ Time average price of imported high-carbon chromium containing 50%-55% chromium as reported by Platt's Metals Week.

8/ Time average price of electrolytic chromium metal as reported by Platt's Metals Week.

9/ Number in parenthesis indicates that imports are greater than exports.

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TABLE 2
CHROMIUM 1/ RELEASED TO THE ENVIRONMENT AND TRANSFERRED BY INDUSTRY AND BY MODE 2/

(Kilograms, contained chromium)

	SIC 3/	1994			1995		
		Released	Transferred	Total	Released	Transferred	Total
Industry:							
Food products	20	4,670	43,200	47,800	5,230	8,140	13,400
Tobacco products	21	–	–	–	–	–	–
Textile mill products	22	3,480	28,800	32,300	2,080	57,200	59,300
Apparel	23	–	–	–	–	–	–
Lumber and wood products	24	3,420	66,100	69,500	2,480	59,500	62,000
Furniture	25	24,300	275,000	300,000	1,400	326,000	328,000
Paper and allied products	26	47,700	13,900	61,500	43,100	9,400	52,500
Printing and publishing	27	116	3,970	4,090	–	5	5
Chemical and allied products	28	8,000,000	1,120,000	9,130,000	7,930,000	759,000	8,690,000
Petroleum and coal	29	35,400	127,000	162,000	21,500	64,200	85,600
Rubber and plastic	30	4,090	355,000	359,000	4,000	250,000	254,000
Leather and leather products	31	8,600	814,000	823,000	7,940	725,000	733,000
Stone, clay, glass, and concrete	32	88,400	800,000	888,000	137,000	986,000	1,120,000
Primary metals	33	1,970,000	39,700,000	41,700,000	2,040,000	30,200,000	32,300,000
Fabricated metals	34	199,000	12,900,000	13,100,000	88,700	14,600,000	14,600,000
Machinery and computer equipment	35	50,800	8,500,000	8,550,000	51,600	8,390,000	8,440,000
Electrical and electronic equipment	36	8,540	884,000	893,000	1,910	900,000	902,000
Transportation equipment	37	63,600	9,600,000	9,660,000	134,000	10,300,000	10,400,000
Instruments	38	2,360	527,000	530,000	2,500	462,000	465,000
Miscellaneous manufacturing	39	2,070	887,000	889,000	2,150	955,000	957,000
Other		4,000	376,000	380,000	3,440	264,000	267,000
Total		10,500,000	77,000,000	87,500,000	10,500,000	69,300,000	79,700,000
Mode:							
Releases:							
To air		536,000	XX	5 4/	546,000	XX	5 4/
To water		81,600	XX	1 4/	69,700	XX	1 4/
To underground		17,300	XX	(5/) 4/	27,600	XX	(5/) 4/
To land:							
Fill		1,450,000	XX	14 4/	1,320,000	XX	13 4/
Treatment		41,000	XX	(5/) 4/	35,400	XX	(5/) 4/
Impoundment		8,330,000	XX	79 4/	8,460,000	XX	81 4/
Other		67,200	XX	1 4/	18,200	XX	(5/) 4/
Total releases		10,500,000	XX	12 6/	10,500,000	XX	13 6/
Transfers:							
To POTW		XX	195,000	(5/) 7/	XX	359,000	(5/) 7/
To off-site location:							
Disposal		XX	7,340,000	10 7/	XX	9,780,000	14 7/
Recycling		XX	67,000,000	87 7/	XX	56,700,000	82 7/
Treatment		XX	2,440,000	3 7/	XX	2,500,000	4 7/
Other		XX	83,000	(5/) 7/	XX	106,000	(5/) 7/
Total transfers		XX	77,000,000	88 6/	XX	69,300,000	87 6/
Total releases plus transfers		XX	87,500,000	XX	XX	79,700,000	XX

XX Not applicable.
1/ Chromium contained in U.S. Environmental Protection Agency categories chromium and chromium compounds.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Standard industrial classification code.
4/ Releases as percent of total releases.
5/ Less than 1/2 unit.
6/ Totals as percent of total releases plus transfers.
7/ Transfers as percent of total transfers.

NOTE: Air included point and nonpoint (that is, stack and fugitive) sources. POTW is publicly owned treatment works.

Source: U.S. Environmental Protection Agency, Toxic Release Inventory (July 1997).

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TABLE 3
PRINCIPAL U.S. PRODUCERS OF CHROMIUM PRODUCTS IN 1996, BY INDUSTRY

Industry and company	Plant
Metallurgical:	
Elkem A/S, Elkem Metals Co.	Marietta, OH.
Macalloy Corp.	Charleston, SC.
Refractory:	
General Refractories Co.	Lehi, UT.
Harbison-Walker Refractories, a subsidiary of Global Industrial Technologies	Hammond, IN.
National Refractories & Minerals Corp.	Moss Landing, CA, and Columbiana, OH.
North American Refractories Co. Ltd.	Womelsdorf, PA.
Chemical:	
American Chrome & Chemicals Inc.	Corpus Christi, TX.
Occidental Chemical Corp.	Castle Hayne, NC.

TABLE 4
PRODUCTION, SHIPMENTS, AND STOCKS OF CHROMIUM FERROALLOYS AND METAL, AND OTHER CHROMIUM MATERIALS IN THE UNITED STATES 1/

(Metric tons)

	Net production			
Year	Gross weight	Chromium content	Net shipments	Producer stocks, Dec. 31
1995	72,500	49,500	72,100	8,430
1996	36,800	26,400	38,800	6,450

1/ Data are rounded to three significant digits.

TABLE 5
CONSUMPTION OF CHROMITE AND TENOR OF ORE USED BY PRIMARY CONSUMER GROUPS IN THE UNITED STATES 1/

	Chemical and metallurgical industry		Refractory industry		Total	
Year	Gross weight (metric tons)	Average Cr_2O_3 (percentage)	Gross weight (metric tons)	Average Cr_2O_3 (percentage)	Gross weight (metric tons)	Average Cr_2O_3 (percentage)
1995	W	43.9	W	42.1	351,000	43.8
1996	W	45.6	W	35.2	282,000	45.2

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 6
U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL, BY END USE 1/

(Metric tons, gross weight unless noted)

End use	Ferrochromium		Ferro-chromium-silicon	Other	Total
	Low-carbon 2/	High-carbon 3/			
1995:					
Steel:					
Carbon	4,140 r/	7,660 r/	163 r/	W	12,000 r/
Stainless and heat-resisting	7,970 r/	209,000	32,800	W	250,000
Full-alloy	3,930 r/	28,700 r/	1,380	W	34,000 r/
High-strength, low-alloy, and electric	1,280 r/	2,210 r/	7,320 r/	--	10,800 r/
Tool	W	4,140	W	W	4,140
Cast irons	969 r/	3,220 r/	W	384	4,570 r/
Superalloys	2,290 r/	4,940	--	3,360 r/	10,600 r/
Welding materials 4/	W	89	W	W	89
Other alloys 5/	607 r/	363	--	1,530	2,500 r/
Miscellaneous and unspecified	1,730 r/	223	5,840	1,470	9,260 r/
Total 6/	22,900 r/	261,000 r/	47,500	6,740 r/ 7/	338,000
Chromium content	15,400 r/	154,000 r/	18,100	5,350 r/	193,000
Stocks, Dec. 31, 1995	1,940 r/	16,500 r/	3,810 r/	513 r/ 8/	22,800 r/
1996:					
Steel:					
Carbon	3,850	9,230	163	555	13,800
Stainless and heat-resisting	7,990	202,000	32,400	W	243,000
Full-alloy	3,750	25,600	1,620	47	31,000
High-strength, low-alloy, and electric	2,090	2,110	7,240	--	11,400
Tool	W	5,040	W	W	5,040
Cast irons	W	3,020	W	312	3,340
Superalloys	2,200	5,040	--	3,540	10,800
Welding materials 4/	83	67	1	294	445
Other alloys 5/	318	360	--	1,330	2,010
Miscellaneous and unspecified	2,910	305	8,900	163	12,300
Total 6/	23,200	253,000	50,300	6,240 9/	333,000
Chromium content	15,600	151,000	17,800	5,190	190,000
Stocks, Dec. 31, 1996	1,790	23,900	1,560	349 10/	27,600

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Low-carbon ferrochromium contains less than 3% carbon.

3/ High-carbon ferrochromium contains 3% or more carbon.

4/ Includes structural and hard-facing welding material.

5/ Includes cutting materials and magnetic, aluminum, copper, nickel, and other alloys.

6/ Includes estimates.

7/ Includes 4,600 tons of chromium metal.

8/ Includes 264 tons of chromium metal.

9/ Includes 4,620 tons of chromium metal.

10/ Includes 211 tons of chromium metal.

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TABLE 7
U.S. CONSUMER STOCKS OF CHROMITE, CHROMIUM FERROALLOYS, AND METAL, DECEMBER 31 1/

(Metric tons, gross weight)

Industry	1995	1996
Chromite:		
Chemical and metallurgical	194,000	165,000
Refractory	10,900	7,890
Total	205,000	173,000
Chromium ferroalloy and metal:		
Low-carbon ferrochromium	1,940 r/	1,790
High-carbon ferrochromium	16,500 r/	23,900
Ferrochromium-silicon	3,810 r/	1,560
Other 2/	513 r/	349
Total	22,800 r/	27,600

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes chromium briquets, exothermic chromium additives, and other miscellaneous chromium alloys. Also includes chromium metals stocks of 211 tons in 1996 and 264 tons in 1995.

TABLE 8
U.S. GOVERNMENT STOCKPILE YEAREND INVENTORIES 1/ AND CHANGE FOR CHROMIUM 2/

(Metric tons, gross weight)

Material	1995	1996	Change 3/	
			Quantity	Percent
Chromite:				
Chemical	220,000	220,000	--	--
Metallurgical	773,000	645,000	(128,000)	(20%)
Refractory	328,000	322,000	(6,140)	(2%)
Chromium ferroalloys:				
Ferrochromium-silicon	52,900	52,700	(253)	(4/)
High-carbon ferrochromium	738,000	718,000	(20,100)	(3%)
Low-carbon ferrochromium	283,000	283,000	--	--
Chromium metal:				
Aluminothermic	2,670	2,670	--	--
Electrolytic	5,020	5,050	36	1%

1/ Includes specification- and nonspecification-grade materials.

2/ Data are rounded to three significant digits.

3/ Number in parentheses indicates decrease.

4/ Less than 1/2 unit.

Source: Defense Logistics Agency.

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TABLE 9
TIME-VALUE 1/ RELATIONS FOR CHROMITE ORE, FERROCHROMIUM, AND CHROMIUM METAL 2/

(Average annual value, dollars per metric ton)

Material	1995		1996	
	Contained chromium	Gross weight	Contained chromium	Gross weight
Chromite ore:				
Not more than 40% chromic oxide	630	153	594	135
More than 40% but less 46% chromic oxide	262	74	327	98
46% or more chromic oxide	232	76	282	91
Total	247	80	293	93
Ferrochromium:				
Low-carbon 3/	1,880	1,230	2,270	1,440
High-carbon 4/	1,220	731	976	564
Total	1,320	805	1,180	690
Chromium metal	XX	6,450	XX	7,010

XX Not applicable.
1/ Customs value per ton of chromium contained in imported material.
2/ Data are rounded to three significant digits.
3/ Carbon not more than 4%.
4/ More than 4% carbon.

TABLE 10
PRICE QUOTATIONS FOR CHROMIUM MATERIALS AT BEGINNING AND END OF 1996

Material	January	December	Year average
Dollars per metric ton of product:			
Chromite ore:			
South Africa	70 - 80	70 - 80	75
Turkey	220 - 230	220 - 230	225
Cents per pound of chromium:			
High-carbon ferrochromium:			
Imported:			
50% to 55% chromium	62 - 64	39.8 - 42.9	51
60% to 65% chromium	62 - 64	41 - 42.5	43
Low-carbon ferrochromium:			
Domestic:			
0.05% carbon	95	95	95
0.015% carbon (Simplex)	166	166	166
Imported:			
0.05% carbon	119 - 123	112 - 120	137
0.10% carbon	110 - 112	97 - 103	118
Cents per pound of product:			
Chromium metal (domestic):			
Electrolytic	415.0	415.0	415.0
Elchrome	490.0	530.0	515.0

Source: Platt's Metals Week.

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TABLE 11
U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE 1/

HTSUSA 2/	Type	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)	Principal destinations, 1996
2610.00.0000	Chromite ore and concentrate, gross weight	17,800	$3,430	69,400	$11,100	China (53%); Russia (21%); Canada (20%); Mexico (4%).
	Metal and alloys:					
8112.20.0000	Chromium metal, gross weight 3/	714	7,820	1,330	12,800	Japan (47%); Canada (18%); Belgium (17%); Germany (12%).
	Chromium ferroalloys:					
7202.41.0000	High-carbon ferrochromium, gross weight 4/	6,610	8,120	12,800	9,650	Japan (40%); Mexico (36%); Canada (21%).
7202.41.0000	High-carbon ferrochromium, contained weight 4/	4,060	8,120	7,800	9,650	
7202.49.0000	Low-carbon ferrochromium, gross weight 5/	2,010	3,490	2,780	4,020	Netherlands (31%); Canada (28%); Mexico (28%); Sweden (4%).
7202.49.0000	Low-carbon ferrochromium, contained weight 5/	1,220	3,490	1,630	4,020	
7202.50.0000	Ferrochromium-silicon, gross weight	741	860	252	286	Canada (100%).
7202.50.0000	Ferrochromium-silicon, contained weight	259	860	88	286	
	Total ferroalloys, gross weight	9,360	12,500	15,800	14,000	
	Total ferroalloys, contained weight	5,540	12,500	9,520	14,000	
	Chemicals: (gross weight)					
	Chromium oxides:					
2819.10.0000	Chromium trioxide	7,590	14,500	11,000	21,000	Brazil (23%); Canada (21%); Mexico (13%); Australia (9%); Japan (7%); South Africa (6%); Korea, Republic of (5%).
2819.90.0000	Other	2,460	14,600	2,110	11,100	Canada (36%); Netherlands (22%); Japan (9%); Malaysia (5%); Australia (4%); Hong Kong (4%).
2833.23.0000	Chromium sulfates	187	412	1,060	3,330	Mexico (45%); Canada (44%); Germany (12%).
	Salts of oxometallic or peroxometallic acids:					
2841.20.0000	Zinc and lead chromate	969	3,280	928	2,620	Canada (96%).
2841.30.0000	Sodium dichromate	25,800	18,900	31,500	26,300	Mexico (43%); China (16%); Thailand (11%); Uruguay (6%).
2841.40.0000	Potassium dichromate	35	102	66	122	Brazil (49%); Canada (32%); Japan (11%).
2841.50.0000	Other chromates, dichromates, and peroxchromates	410	1,620	385	1,640	Canada (67%); Australia (9%); United Kingdom (9%); Mexico (8%).
3206.20.0000	Pigments and preparations, gross weight	1,260	6,020	2,100	6,920	Canada (66%); Mexico (9%); Singapore (7%); Japan (5%).

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.
3/ Articles thereof and waste and scrap.
4/ More than 4% carbon.
5/ Not more than 4% carbon.

Source: Bureau of the Census.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF CHROMITE ORE, BY COUNTRY 1/

Country	Not more than 40% Cr_2O_3 (HTSUSA 2/ 2610.00.0060)			More than 40% but less than 46% Cr_2O_3 (HTSUSA 2/ 2610.00.0040)			46% or more Cr_2O_3 (HTSUSA 2/ 2610.00.0020)			Total		
	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)
1995:												
Canada	--	--	--	--	--	--	39	24	$9	39	24	$9
India	--	--	--	--	--	--	25,400	12,400	4,090	25,400	12,400	4,090
Philippines	11,100	4,000	$1,700	--	--	--	--	--	--	11,100	4,000	1,700
South Africa	171	39	27	14,800	6,110	$1,100	201,000	96,400	13,200	216,000	103,000	14,300
Venezuela	321	80	49	--	--	--	--	--	--	321	80	49
Total	11,600	4,120	1,780	14,800	6,110	1,100	226,000	109,000	17,200	253,000	119,000	20,100
1996:												
Canada	20	8	3	--	--	--	--	--	--	20	8	3
Philippines	7,940	2,620	1,060	--	--	--	--	--	--	7,940	2,620	1,060
South Africa	--	--	--	25,400	11,100	2,480	217,000	102,000	19,700	242,000	113,000	22,100
Venezuela	46	18	16	--	--	--	--	--	--	46	18	16
Zimbabwe	23	9	3	--	--	--	--	--	--	23	9	3
Total	8,030	2,650	1,080	25,400	11,100	2,480	217,000	102,000	19,700	250,000	116,000	23,200

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.

Source: Bureau of the Census.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY 1/

Country	Low-carbon (not more than 3% carbon) (HTSUSA 2/ 7202.49.5000)			Medium-carbon (more than 3% carbon but not more than 4% carbon) (HTSUSA 2/ 7202.49.1000)			High-carbon (more than 4% carbon) (HTSUSA 2/ 7202.41.0000)			Total (all grades)		
	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)
1995:												
Albania	--	--	--	--	--	--	8,700	5,240	$5,170	8,700	5,240	$5,170
Argentina	70	51	$107	--	--	--	--	--	--	70	51	107
Brazil	--	--	--	--	--	--	7,000	3,690	4,660	7,000	3,690	4,660
Canada	--	--	--	--	--	--	19	11	22	19	11	22
China	5,240	3,350	6,830	227	151	$127	12,400	8,020	11,000	17,800	11,500	17,900
Croatia	--	--	--	6	4	9	14,300	8,820	10,800	14,300	8,820	10,800
Estonia	123	87	140	--	--	--	--	--	--	123	87	140
Finland	--	--	--	--	--	--	8,610	4,850	5,270	8,610	4,850	5,270
France	--	--	--	--	--	--	7	5	9	7	5	9
Germany	6,830	4,770	14,600	--	--	--	7	5	15	6,840	4,780	14,600

See footnotes at end of table.

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TABLE 13--Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY 1/

Country	Low-carbon (not more than 3% carbon) (HTSUSA 2/ 7202.49.5000)			Medium-carbon (more than 3% carbon but not more than 4% carbon) (HTSUSA 2/ 7202.49.1000)			High-carbon (more than 4% carbon) (HTSUSA 2/ 7202.41.0000)			Total (all grades)		
	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thousands)
1995--Continued:												
India	--	--	--	--	--	--	11,600	6,970	$10,300	11,600	6,970	$10,300
Japan	525	348	$1,350	--	--	--	269	169	309	793	517	1,660
Kazakstan	7,040	4,370	7,730	5,840	3,840	$5,750	34,300	22,800	28,000	47,200	31,000	41,500
Latvia	1,120	727	1,150	--	--	--	15,500	10,700	13,300	16,600	11,500	14,500
Netherlands	(3/)	(3/)	(3/)	--	--	--	--	--	--	(3/)	(3/)	(3/)
Norway	--	--	--	--	--	--	6,170	3,850	5,200	6,170	3,850	5,200
Philippines	--	--	--	--	--	--	2,580	1,530	2,390	2,580	1,530	2,390
Poland	--	--	--	--	--	--	1,410	801	1,020	1,410	801	1,020
Russia	28,100	19,500	37,200	--	--	--	68,300	45,800	57,800	96,400	65,300	95,000
Slovenia	--	--	--	--	--	--	1,250	750	1,140	1,250	750	1,140
South Africa	14,300	8,050	10,900	--	--	--	118,000	60,000	58,900	132,000	68,000	69,800
Sweden	--	--	--	--	--	--	38	26	49	38	26	49
Turkey	956	699	1,240	1,500	930	1,170	82,400	51,000	69,000	84,800	52,600	71,400
Ukraine	185	131	237	--	--	--	--	--	--	185	131	237
United Kingdom	61	46	132	--	--	--	162	107	201	224	153	332
Zimbabwe	1,340	716	1,320	--	--	--	29,000	18,400	24,000	30,300	19,100	25,300
Total	65,800	42,800	82,900	7,570	4,930	7,060	422,000	254,000	309,000	495,000	301,000	399,000
1996:												
Albania	--	--	--	--	--	--	8,170	4,730	5,170	8,170	4,730	5,170
China	8,180	5,370	12,600	--	--	--	9,860	6,280	6,540	18,000	11,600	19,100
Croatia	20	13	17	--	--	--	9,430	5,880	6,110	9,450	5,900	6,130
Estonia	--	--	--	--	--	--	8,310	5,400	5,360	8,310	5,400	5,360
Finland	--	--	--	--	--	--	9,020	4,790	4,820	9,020	4,790	4,820
Germany	9,200	6,410	21,100	--	--	--	19	14	38	9,220	6,430	21,100
India	1,360	933	2,220	--	--	--	6,150	3,810	3,860	7,500	4,750	6,080
Japan	533	345	1,380	--	--	--	18	12	25	551	357	1,400
Kazakstan	152	106	257	--	--	--	77,600	46,800	45,600	77,700	46,900	45,800
Philippines	--	--	--	36	23	47	--	--	--	36	23	47
Russia	18,000	11,900	27,200	--	--	--	21,600	11,300	16,200	39,700	23,100	43,400
South Africa	18,900	10,600	16,800	--	--	--	105,000	53,400	45,100	124,000	64,000	61,800
Turkey	902	652	1,890	--	--	--	43,800	27,100	27,400	44,700	27,800	29,200
United Kingdom	313	201	575	--	--	--	2,030	1,090	973	2,340	1,290	1,550
Zimbabwe	3,140	1,930	3,240	--	--	--	58,200	36,700	35,300	61,400	38,700	38,600
Total	60,700	38,400	87,200	36	23	47	359,000	207,000	202,000	420,000	246,000	290,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.
3/ Revised to zero.

Source: Bureau of the Census.

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TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE 1/

HTSUSA 2/	Type	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)	Principal sources, 1996
	Metals and alloys:					
	Chromium metal:					
8112.20.3000	Waste and scrap, gross weight	109	$542	67	$312	Russia (30%); China (26%); Sweden (23%); Canada (20%).
8112.20.6000	Other than waste and scrap, gross weight	6,930	44,900	8,670	60,900	Russia (42%); China (18%); France (18%); United Kingdom (15%).
7202.50.0000	Ferrochromium-silicon, gross weight	49,600	32,500	49,400	33,200	Russia (36%); Kazakstan (32%); Zimbabwe (15%); China (12%).
7202.50.0000	Ferrochromium-silicon, contained weight	17,300	32,500	21,100	33,200	
	Chemicals: (gross weight)					
	Chromium oxides and hydroxides:					
2819.10.0000	Chromium trioxide	4,060	7,270	3,800	7,060	Kazakstan (56%); Germany (22%); Netherlands (11%).
2819.90.0000	Other	5,030	14,500	4,350	13,100	Canada (33%); Germany (28%); Japan (23%); China (10%).
2833.23.0000	Sulfates of chromium	170	127	192	159	Mexico (58%); South Africa (21%); Germany (11%); United Kingdom (10%).
	Salts of oxometallic or peroxometallic acids:					
2471.20.0000	Chromates of lead and zinc	396	925	114	260	Norway (37%); France (19%); Philippines (14%); United Kingdom (14%); Poland (13%).
2841.30.0000	Sodium dichromate	7,000	4,660	5,100	4,040	United Kingdom (85%); Argentina (7%).
2841.40.0000	Potassium dichromate	377	661	381	718	United Kingdom (64%); Russia (32%); Mexico (3%).
2841.50.0000	Other chromates and dichromates; peroxochromates	919	2,040	573	1,260	United Kingdom (93%); France (3%); Austria (2%); Canada (2%).
2849.90.2000	Chromium carbide	200	1,970	190	2,270	Japan (50%); United Kingdom (30%); Germany (19%).
	Pigments and preparations based on chromium: (gross weight)					
3206.20.0010	Chrome yellow	4,700	10,400	7,020	17,600	Canada (74%); Mexico (17%); Hungary (4%); Philippines (3%).
3206.20.0020	Molybdenum orange	673	2,250	1,840	5,670	Canada (97%); Japan (3%).
3206.20.0030	Zinc yellow	136	314	127	283	Norway (100%).
3206.20.0050	Other	805	3,060	929	3,530	France (51%); Germany (11%); Mexico (8%); Poland (7%); Canada (6%).

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.

Source: Bureau of the Census.

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TABLE 15
PRINCIPAL WORLD CHROMITE PRODUCERS, 1996

Country 1/	Company
Albania	Albchrome (Government owned).
Brazil	Bayer AG (Germany).
	Coitezeiro Mineração S.A.
	Cia. de Ferro-Ligas da Bahia S.A.
	Cia. de Mineração Serra de Jacobina S.A.
	Mineração Vale do Jacurici S.A.
	Indústria e Comércio de Minérios S.A.
	Invituruí Mineração S.A.
	Magnesita S.A.
	Piunhiense Mineração Ltda.
	Rada Mineração Ltda.
Finland	Outokumpu Oy.
	Outokumpu Steel Oy.
	Outokumpu Chrome Oy.
India	Ferro Alloys Corp. Ltd.
	Mysore Mineral Ltd.
	Orissa Mining Corp. Ltd. (Government owned).
	Tata Iron and Steel Co. Ltd.
Indonesia	PT. Palabim Mining-PT. Bituminuse
Japan	Japan Chrome Industry Co. Ltd.
Kazakstan	Donskoy Ore Dressing Complex.
Philippines	Acoje Mining Co. Inc.
	Benguet Corp.
	Philchrome Mining Corp.
	Velore Mining Corp.
Russia	Saranov Complex.
South Africa 2/	African Mining and Trust Co. Ltd.
	Rustenburg Minerals Development Co. (Pty.) Ltd.
	Zeerust Chrome Mine Ltd.
	Bayer AG (Germany).
	Bayer (Pty.) Ltd.
	Canadian Gold S.A. (Pty.) Ltd.
	Goudini Chrome (Pty.) Ltd.
	Chromecorp Holdings (Pty.) Ltd.
	Chrome Resources (Pty.) Ltd.
	Consolidated Metallurgical Industries Ltd.
	Hernic Chrome
	Hernic Mining (Pty.) Ltd.
	Lebowa Development Corp. Ltd.
	Dilokong Chrome Mine (Pty.) Ltd.
	Pilanesberg Chrome (Pty.) Ltd.
	Rooderand Chrome Mine (Pty.) Ltd.
	Samancor Ltd.
	Batlhako Mining Ltd.
	Eastern Chrome Mines.
	Doornbosch Mines.
	Lannex Joint Venture.
	Montrose Mine.
	Groothoek Section.
	Jagdlust Section.
	Montrose Section.
	Mooihoek Mine.
	Steelpoort Mine.
	Tweefontein Mine.
	Western Chrome Mines.
	Buffelsfontein Section.
	Elandsdrift Section.
	Henery Gould Section.
	Millsell Section.
	Mooinooi Section.
	Waterloof Section.
	Vereeniging Refractories Ltd.
	Bophuthatswana Chrome Co. (Pty.) Ltd.
	Marico Chrome Corp. Ltd.
Sudan	Advanced Mining Works Ltd.
	Blue Nile Mines Co. Ltd.

See footnotes at end of table.

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TABLE 15--Continued
PRINCIPAL WORLD CHROMITE PRODUCERS, 1996

Country 1/	Company
Turkey	Aycan Madencilik Ltd. Sti.
	Bilfer Madencilik A.S.
	Birlik Madencilik Sanayi ve Ticaret A.S.
	Cevher Madencilik ve Ticaret A.S.
	Dedeman Madencilik Turzim Sanayi ve Ticaret A.S.
	Ege Metal Endüstri A.S.
	Etibank General Management (Government owned).
	Hayri Ögelman Madencilik Ltd. Sti.
	Tekfen Dis. Ticaret A.S.
	Tevfik Refik Bayoglu Madencilik.
	Tut. Gen. Ticaret Ltd. Sti.
	Turk Maadin Sti. A.S.
Zimbabwe	Zimbabwe Alloys Ltd.
	Zimasco (Pvt.) Ltd.

1/ Other chromite-producing countries included Burma, China, Cuba, Egypt, Iran, Macedonia, Madagascar, Morocco, Oman, and Pakistan.
2/ Includes Bophuthatswana.

TABLE 16
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 1996

Country 1/	Company
Albania	Albchrome Ltd. (Government owned).
Brazil	Cia. de Ferro-Ligas da Bahia S.A.
China	Chongqing Ferroalloy Works (Government owned).
	Emei Ferroalloy Works (Government owned).
	Hanzhong Ferroalloy Works (Government owned).
	Hengshan Iron and Steel Works (Government owned).
	Hunan Ferroalloy Works Government owned).
	Jiangyin Ferroalloy Factory (Government owned).
	Jilin Ferroalloy Works (Government owned).
	Jinzhou Ferroalloy Works (Government owned).
	Liaoyang Ferroalloy Works (Government owned).
	Nanjing Ferroalloy Plant (Government owned).
	Shanghai Ferroalloy Works (Government owned).
	Xibei Ferroalloy Works (Government owned).
Croatia	Dalmacija Ferro-Alloys Works.
Finland	Outokumpu Oy.
	Outokumpu Steel Oy.
	Outokumpu Chrome Oy.
Germany	Elektrowerk Weisweiler GmbH.
India	Deepak Ferro-Alloys Ltd.
	Eastern Metals & Ferro-Alloys Ltd.
	Ferro Alloys Corp. Ltd.
	Charge Chrome Works.
	Ferroalloys Works.
	GMR Vasavi Industries Ltd.
	Hi-Tech Electrothermics (Pvt.) Ltd.
	Indian Metals & Ferro Alloys Ltd.
	Indian Charge Chrome Ltd.
	Industrial Development Corp.
	Ispat Alloys Ltd.
	Jindal Ferro Alloys Ltd.
	Mandsaur Ferro Alloys Ltd.
	Monnet Industries Ltd.
	Nav Chrome Ltd.
	Nava Bharat Ferro Alloys Ltd.
	Standard Chrome Ltd.
	Tata Iron and Steel Co. Ltd.
	Bamnipal Plant.
	Joda Plant.
	VBC Ferro-Alloys Ltd.
	Visvesvaraya Iron & Steel Ltd. (State owned).
	V.K. Ferroalloys (Pvt.) Ltd.

See footnotes at end of table.

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TABLE 16--Continued
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 1996

Country 1/	Company
Italy	Acciaierie e Ferriere Lombarde Falck SpA.
	Darfo s.r.l.
	Ferroleghe SpA.
Japan	Japan Metals and Chemicals Co. Ltd.
	Nippon Denko Co. Ltd.
	NKK Corp.
	Pacific Metals Co. Ltd.
	Showa Denko K.K.
Kazakstan	Aktubinsk Ferroalloy Works.
	Aksu (formerly Yermakovsky) Ferroalloy Plant.
Norway	Elkem A/S.
Philippines	Ferrochrome Philippines Inc.
	Integrated Chrome Corp.
	Philippine Mineral & Alloy Corp.
Poland	Huta "Laziska" Ferroalloy Plant.
Romania	S.C. Ferom S.A.
Russia	Chelyabinsk Electrometallurgical Works.
	Klutchevsk Ferroalloy Plant.
	Serovsk Ferroalloy Works.
Slovakia	Oravske Ferozliatinarske Zavody.
Slovenia	Tovarna Dusika Ruse-Metalurgija d.o.o.
South Africa	Assoc. Manganese Mines of South Africa Ltd.
	Feralloys Ltd.
	Chromecorp Holdings Ltd.
	Chrome Resources (Pty.) Ltd.
	Ferrochrome Division.
	Johannesburg Consolidated Investment Co. Ltd.
	Consolidated Metallurgical Industries Ltd.
	Lydenburg Works.
	Rustenburg Works.
	Purity Ferrochrome (Pty.) Ltd.
	Samancor Ltd.
	Batlhako Ferrochrome Ltd.
	Ferrometals Division.
	Middelburg Ferrochrome Division.
	Palmiet Ferrochrome Division.
	Tubatse Ferrochrome Division.
Sweden	Vargön Alloy AB.
Turkey	Etibank General Management (Government owned).
United States	Elkem Metals Co.
	Macalloy Corp.
Zimbabwe	Zimbabwe Alloys Ltd.
	Zimasco (Pvt.) Ltd.

1/ Other ferrochromium-producing countries include Chile, Mexico, Spain and Taiwan.

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TABLE 17
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1992	1993	1994	1995	1996
Albania	322,000	282,000	222,879	245,813 r/	235,816
Brazil 4/	448,980	307,577	359,788	447,963 r/	450,000 e/
Burma e/	6,200	1,000	1,000	1,000 r/	1,000
China e/	25,000	54,000	62,000	94,000 r/	80,000
Cuba e/	50,000	50,000	50,000	50,000	50,000
Egypt e/	600	600	600	600	600
Finland	499,000	511,000	572,747	597,605 r/	582,174
Greece e/ 5/	4,000	2,500	--	--	--
India	1,082,069 r/	1,069,603 r/	909,076 r/	1,536,386 r/	1,363,205
Indonesia e/	2,000	2,500	2,500	10,000 r/	13,300
Iran 6/	130,265	114,780 r/	129,000	129,000 e/	129,000 e/
Japan e/	8,000	7,000	7,000	7,000	7,000
Kazakstan	3,500,000 e/	2,900,000 e/	2,020,000	2,871,000 r/	1,190,000
Macedonia e/	6,000	5,000	5,000	5,000	6,000
Madagascar	160,700	144,200	90,200	102,859 r/	137,210 p/
Morocco 7/	302 r/	-- r/	-- r/	-- r/	--
New Caledonia	8,169	--	--	--	--
Oman	1,764	10,236 r/	6,166	5,300	15,000
Pakistan	22,852	22,154	6,240	17,000 e/	27,987
Philippines	65,721 r/	61,732 r/	76,003 r/	111,035 r/	78,345
Russia	121,400	120,800	143,000	151,400	96,700
South Africa 8/	3,363,481	2,838,000 r/	3,599,000 r/	5,085,000 r/	5,017,550
Sudan e/	10,000	11,500	25,000	44,988 r/ 9/	12,000
Turkey 10/	758,732 r/	767,313 r/	1,270,431 r/	2,080,043 r/	2,000,000 e/
United Arab Emirates	1,000 e/	20,000 e/	55,000 r/	37,000 r/	56,000
Zimbabwe	522,013	252,033	516,801	707,433 r/	697,311
Total	11,100,000 r/	9,560,000 r/	10,100,000 r/	14,300,000 r/	12,200,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 25, 1997.

3/ Figures for all countries represent marketable output unless otherwise noted.

4/ Average Cr_2O_3 content was as follows: 1992--44.1%; 1993--41.0%; 1994--41.3%; 1995--42.2% (revised); and 1996--42.2%.

5/ Direct-shipping ore plus concentrate.

6/ Concentrate.

7/ Chromite production from Compagnie de Tifnout Tiranimine (CTT) discontinued.

8/ Includes production by Bophuthatswana.

9/ Reported figure.

10/ Salable product: direct-shipping lump ore plus concentrate.

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TABLE 18
FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Albania	21,650 r/	35,600 r/	33,764 r/	42,986	31,189 3/
Brazil 4/	91,100	83,892	77,163	95,840	72,609 3/
Chile	2,110	680	1,579	2,730	2,700
China e/	410,000	372,000	370,000	400,000	450,000
Croatia	56,456	27,336	31,704 r/	26,081 r/	10,559 3/
Czechoslovakia 4/ 5/	52,500	XX	XX	XX	XX
Finland	187,100	218,370	253,501 r/	246,805 r/	236,000
France	6,694	--	--	--	--
Germany	26,520	16,400	17,283	18,000 r/	16,000
India 6/	192,674 r/	234,500	251,459	300,000 e/	300,000
Iran 7/	--	--	7,150 r/	11,900 r/	15,000
Italy	60,315	53,504	22,650	51,017	29,915 3/
Japan 4/	275,615	211,102	204,181	221,425	200,365 3/
Kazakstan	400,000 e/	327,896	200,000 e/	486,000 r/	352,000
Macedonia	3,958	4,376	3,164	3,765	3,780 3/
Mexico	70 e/	--	--	--	-- 3/
Norway	102,000	80,000	120,000	148,000	108,800 3/
Philippines	27,400	11,908	16,186	50,450	--
Poland	35,322	38,449	7,353 r/	18,334	18,000
Romania	6,971 r/	3,907	3,885	15,053	9,650 3/
Russia	400,000 e/	255,900	265,525	200,000 e/	50,000
Slovakia 4/ 5/	XX	50,600	48,555	65,260	65,000
Slovenia	17,104	9,000	12,592	18,876	19,000
South Africa 8/	770,600	833,600	1,103,612	1,386,400 r/	1,400,000
Spain	--	2,390	2,300	1,320	805 3/
Sweden	133,300	127,543	134,076	130,170	138,110 3/
Turkey	85,755	90,030	97,585	94,251 r/	101,450 3/
United States 9/	60,900	63,000	67,400	72,500	36,800 3/
Zimbabwe 4/	190,994	124,000	182,852	254,142	261,918 3/
Total	3,620,000 r/	3,280,000	3,540,000 r/	4,360,000 r/	3,930,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 25, 1997.

3/ Reported figure.

4/ Includes high- and low-carbon ferrochromium.

5/ Czechoslovakia was dissolved on Dec. 31, 1992. All production for Czechoslovakia in 1992 came from Slovakia.

6/ Includes ferrochrome and charge chrome.

7/ Production began in 1994.

8/ Includes high- and low-carbon ferrochromium and ferrochromium-silicon.

9/ Includes high- and low-carbon ferrochromium, ferrochromium-silicon, chromium metal, and other chromium materials.

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TABLE 19
WORLD CHROMIUM ANNUAL PRODUCTION CAPACITY OF CHROMITE ORE, FERROCHROMIUM, CHROMIUM METAL, CHROMIUM CHEMICALS, AND STAINLESS STEEL IN 1996 1/

(Thousand metric tons, contained chromium)

	Ore	Ferro-chromium	Metal	Chemicals	Stainless steel
Albania	150	32	–	–	–
Argentina	–	–	–	6	–
Austria	–	–	–	–	12
Bangladesh	–	–	–	–	3
Belgium	–	–	–	–	107
Brazil	135	89	(2/)	12	37
Burma	(2/)	–	–	–	–
Canada	–	–	–	–	32
Chile	–	2	–	–	–
China	13	293	4	21	68
Croatia	–	42	–	–	–
Cuba	14	–	–	–	7
Egypt	1	–	–	–	–
Finland	211	131	–	–	89
France	–	–	5	–	163
Germany	–	28	(2/)	24	255
Greece	21	–	–	–	–
India	309	195	(2/)	8	100
Indonesia	20	–	–	–	–
Iran	34	83	–	2	–
Italy	–	64	–	–	182
Japan	3	146	1	20	660
Kazakstan	1,100	330	–	42	–
Korea, North	–	32	–	–	–
Korea, Republic of	–	–	–	–	150
Macedonia	3	7	–	5	–
Madagascar	21	–	–	–	–
Mexico	–	2	–	5	–
Norway	–	88	–	–	–
Oman	6	–	–	–	–
Pakistan	10	–	–	3	–
Philippines	60	60	–	–	–
Poland	–	16	–	3	–
Romania	–	26	–	9	–
Russia	40	233	14	60	330
Slovakia	–	39	–	–	–
Slovenia	–	11	–	–	–
South Africa	1,700	1,250	–	–	95
Spain	–	–	–	–	140
Sudan	2	–	–	–	–
Sweden	–	97	–	–	105
Taiwan	–	1	–	–	83
Thailand	(2/)	–	–	–	–
Turkey	580	103	–	10	54
Ukraine	–	–	–	–	33
United Arab Emirates	8	–	–	–	–
United Kingdom	–	–	4	52	92
United States	–	83	3	53	390
Zimbabwe	170	169	–	–	–
Total	4,610	3,650	32	336	3,190

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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CLAYS

By Robert L. Virta

The amount of clay sold or used by domestic producers remained unchanged from the 1996 levels of 43.1 million metric tons valued at $1.7 billion. Production of common clay increased while all other clay types decreased. Common clays accounted for 61% of the tonnage. Kaolin accounted for 64% of the value of clays produced. Imports increased to 44,600 tons valued at $21 million. Exports increased to 4.83 million tons valued at $825 million. (*See table 1.*)

Legislation and Government Programs

Clay mining has an environmental impact because of the disturbance to the land. Overburden is moved and clays are removed, leaving a depression or pit. State laws usually require leveling or recontouring of the disturbed area and planting trees or grasses to prevent or minimize erosion. For processing, the impoundment of slimes and dust control are usually required. The rules for disposal of coarse tailings are similar to or included with those laws governing reclamation of the mined area.

The Environmental Protection Agency issued proposed revisions to its standards of performance for new stationary sources for nonmetallic mineral processing plants (40 Code of Federal Regulations part 60, subpart 000). The proposed revisions affect the designation of affected facility, the definition of "wet screening operation," the particulate matter standard, test methods and procedures, and reporting and recording (Environmental Protection Agency, 1996).

The Food and Drug Administration issued a proposed rule for the permanent listing of color additive lakes. Lakes are water-insoluble pigments composed of a water-soluble straight color adsorbed onto an insoluble substrate through the use of a precipitant. The agency tentatively concluded that kaolin meeting U.S. Pharmaecopia specifications is safe for use as a substrate in lakes for drug and cosmetic use (Food and Drug Administration, 1996).

An International Agency for Research on Cancer panel evaluated the health risk posed by exposure to crystalline and amorphous silica, palygorskite, sepiolite, wollastonite, some natural and synthetic zeolites (other than erionite), and coal dust and para-aramid fibrils. The panel concluded that "crystalline silica inhaled in the form of quartz or cristobalite from occupational sources was classified as carcinogenic to humans (Group 1)." The conclusion was reached on "the basis of a relatively large number of epidemiological studies that together provided sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica under the conditions specified" (International Agency for Research on Cancer, 1996).

Production

Approximately 280 companies operating 739 clay pits or mines mined clays in 1996; of these, 50 companies, many with multiple operations, accounted for approximately 76% of the tonnage and 83% of the value for all types of clay produced and sold or used. Clay production was reported in most States and Puerto Rico except Alaska, Delaware, Hawaii, Rhode Island, Vermont, Wisconsin, and the District of Columbia.

The leading producer States, in descending order, were Georgia, Wyoming, Alabama, Texas, North Carolina, Ohio, California, South Carolina, Indiana, and Missouri. (*See table 2.*)

Most of the clay was mined by open pit methods. Less than 1% of U.S. clay output was from underground mines in 1996. Most of the underground production was in Ohio, Pennsylvania, and West Virginia, where the clays are mainly underclays associated with coal and suitable for refractory uses.

Domestic production data for clays were developed by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations. Of the 681 operations covered by the survey, 481 responded, representing 71% of the total clay and shale production sold or used shown in table 1. Production data for the nonrespondents were estimated from reported prior-year production levels adjusted by trends in the industry and other guidelines.

Ball Clay.—The ball clay industry was small, with 6 producers operating 33 mines in 6 States. Three of the producers were large, diversified firms with widespread foreign and domestic mineral interests.

Production of domestic ball clay decreased to 973,000 tons valued at $43.1 million. Tennessee supplied 70% of the Nation's output, followed by, in descending order of production, Texas, Mississippi, Kentucky, Indiana, and Missouri. Production increased in Tennessee, was unchanged in Indiana, Mississippi, and Texas, and decreased in Kentucky. Water-slurried ball clay was produced only in Kentucky and Tennessee. Air-float ball clay was produced in all six ball clay producing States. (*See table 3.*)

Bentonite.—Twenty firms producing bentonite operated 57 mines in 10 States. Four producers were large, diversified firms with international mineral operations; three of the firms had interests in other types of clay in the United States.

The quantity and value of all varieties of bentonite sold or used decreased to 3.74 million tons valued at $134 million. Production of nonswelling bentonite decreased to 461,000 tons valued at $21.9 million. Alabama led all States in the production of nonswelling bentonite, followed by Mississippi, California, Arizona, Oregon, Utah, Colorado, Nevada, and

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Montana.

Production of swelling bentonite decreased to 3.28 million tons valued at $112 million. Wyoming led all States in the production of swelling bentonite, followed by Montana, Utah, California, Oregon, and Nevada. (*See table 5.*)

American Colloid Co. sold its acid-activated clay operation to Engelhard Corp. American Colloid indicated that the acid-activated clay business no longer met the long-term goals of the company. The company will close its Aberdeen, MI, calcium bentonite facility. Acid-activated clay was used in petrochemical processes and in clarifying mineral and vegetable oils (North American Minerals News, 1996a).

Laporte PLC announced plans to build a $4 to $12 million synthetic silicate plant at its Southern Clay Products in Gonzales, TX. The U.S. market for the sodium magnesium lithium silicate thickener has grown about 400% in the past 4 years (Chemical Week, 1996b).

Common Clay and Shale.—Two hundred firms operated 439 pits in 42 States and Puerto Rico in 1996. Most of these companies also were manufacturers of structural clay products such as clay pipe, sewer pipe, lightweight aggregates, and cement. Less than 10% of the total output usually is sold. Some companies owned and operated several clay pits and plants to cover a large market area.

Domestic sales or use of common clay and shale increased to 26.2 million tons, valued at $144 million. The major producing States were North Carolina, Alabama, Texas, Ohio, Georgia, Indiana, California, South Carolina, Arkansas, and Virginia, in descending order of tonnage. (*See table 7.*)

Fire Clay.—Fire clay producers were mostly refractories manufacturers that used the clays in firebrick and other refractories. Forty-two mines were operated in 1996 by 19 firms in 9 States.

Fire clay sold or used by domestic producers decreased to 505,000 tons valued at $10.7 million. Missouri, was the leading producing State, followed by Ohio, California, Alabama, South Carolina, Oklahoma, Arkansas, New Mexico, and Montana. (*See table 9.*)

Christy Minerals Co. announced plans to expand its Missouri refractory minerals and investment casting minerals plant. The company will increase its storage and screening capacities and add mills and classifiers (North American Minerals News, 1996b).

Fuller's Earth.—Eighteen companies produced fuller's earth from 32 mines in 12 States. Six of the mines were in the attapulgite-type fuller's earth areas of Florida and Georgia; these two States accounted for most of the domestic attapulgite production. Most producers were small, independent firms, but four were large, diversified corporations with international mineral interests.

Production of fuller's earth decreased to 2.60 million tons valued at $278 million. Production of attapulgite-type fuller's earth was 871,000 tons valued at $116 million. Over one-half of this production came from Georgia, followed by Florida, and Nevada. Production in Nevada was of sepiolite-type fuller's earth.

Production of montmorillonite-type fuller's earth was 1.73 million tons valued at $161 million. Mississippi led all States in production, followed by Illinois, Missouri, California, Georgia, Florida, Tennessee, Kansas, Virginia, Texas, and Utah, in decreasing order of production. (*See table 11.*)

Laporte PLC sold Waverly Minerals Products Co. to Süd-Chemie AG. The purchase was made to allow Süd-Chemie to enter the North American absorbents market. Waverly Minerals produces fuller's earth (calcium bentonite) for cat litter and other applications (Industrial Minerals, 1996e).

Engelhard Corp. increased the capacity of its fuller's earth plant in Jackson, MS. The company produces activated bleaching earths at this location for the fats and oils industry (Chemical Market Reporter, 1996).

Ralston Purina Co. purchased and leased land near Richmond, VA, from the VA Clay Co. The clay will be used at Ralston Purina's new $20 million facility to produce kitty litter (Rock Products, 1996).

Oil Dri Corp. reported increased net sales of cat box absorbents in 1996 with increases in brand and private label products (Oil Dri Corp., 1997).

Kaolin.—Thirty-three firms operated 154 kaolin mines in 12 States. Domestic production was 9.12 million tons valued at $1.1 billion. Georgia was the largest kaolin producer, followed by South Carolina, Alabama, Arkansas, California, North Carolina, Florida, Tennessee, Texas, Nevada, Pennsylvania, and Colorado, in decreasing order of production. (*See table 13.*)

Approximately 48% of the kaolin produced was water-washed; followed by calcined, 18%; delaminated, 17%; air-floated, 13%; and unprocessed, 5%. (*See table 14.*) Production of low-temperature (pigment) and high-temperature (refractory) calcined kaolin was 708,000 and 957,000 tons, respectively. (*See table 15.*)

Kaolin production in Georgia was 8.04 million tons valued at $1.05 billion. Over one-half of the production was sold as water-washed, followed by delaminated, calcined, airfloat, and unprocessed. (*See table 16.*) Production in South Carolina was 387,000 tons valued at $18.1 million, all of which was airfloat or unprocessed. (*See table 18.*) Unprocessed kaolin was sold or used in most States in what may be considered to be common clay applications (i.e., brick, cement, pottery, etc.)

Engelhard Corp. reported lower earnings from paper pigments because of a depressed paper market. The company, however, introduced several kaolin-based products that compete with more costly alternative pigments and work better on high-speed papermaking machines. Additionally, the company commercialized a new brightening agent for use in coatings, inks, and plastics (Engelhard Corp., 1997).

Cytec Industries Inc. sold its calcining plant and ore reserves in Georgia to GEO Specialty Chemicals Inc. The plant, which has a calcining capacity of 145,000 tons, supplies all of the kaolin required for Cytec's alum industry. The reserves, located near Andersonville, Georgia, contain 30 million tons of kaolin, bauxitic clay, and bauxite (Industrial Minerals, 1996c).

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C-E Minerals Inc. invested $10 million to install a new sizing line and upgrade an existing sizing line at its Andersonville, GA, plant. The plant gets its raw materials from mines in Andersonville, GA, and Eufaula, AL (Ceramic Industry, 1996).

Consumption

Ball Clay.—The principal domestic ball clay markets were floor and wall tile, pottery, and sanitaryware. (*See table 4.*) Consumption decreased slightly in 1996. Decreased sales for floor and wall tile and pottery were accompanied by increased exports and a larger percentage of sales being placed under the miscellaneous category in table 4.

Bentonite.—Major markets for bentonite were drilling mud, foundry sand, iron ore pelletizing, and pet waste absorbents. Consumption increased 3%, in 1996, mainly for absorbent, foundry sand, pelletizing, and pet waste absorbent applications. Sales and use decreased for ceramic (sanitaryware), drilling mud, and filler and extender (paint and paper) applications. As in previous years, an estimated 100,000 tons of the bentonite reported under domestic consumption was exported to the Canadian iron ore industry. (*See table 6.*)

With regard to the sales of swelling versus nonswelling bentonite, most of the data were concealed to avoid disclosing company proprietary data. More than two-thirds of the bentonite sold for pet waste absorbent applications was swelling bentonite as was the bentonite sold for oil and grease absorbent applications. Only swelling bentonite was sold for adhesives applications. For animal feed applications, more than 60% of bentonite sold was the swelling variety. The bulk of the bentonite sold for ceramics was swelling bentonite and essentially all of the bentonite used in drilling mud applications was the swelling variety. Only swelling bentonite was sold for filler and extender applications. More than two-thirds of the bentonite sold for foundry sand applications was swelling bentonite. All of the bentonite sold for filtering, clarifying, and decolorizing applications was swelling. Bentonite sold for pelletizing iron ore was exclusively swelling bentonite. Most of the bentonite used for civil engineering, waterproofing and sealing was swelling bentonite.

The major uses for swelling bentonite were in iron ore pelletizing, pet waste absorbent, drilling mud, foundry sand, waterproofing and sealing, and animal feed, in decreasing order of consumption. The major uses for nonswelling bentonite were in foundry sand, absorbents, miscellaneous refractories, animal feed, in decreasing order of consumption.

Common Clay and Shale.—Common clay was used most frequently in the manufacture of heavy clay products, including (1) building brick, flue linings, sewer pipe, drain tile, structural tile, and terra cotta; (2) portland cement clinker; and (3) lightweight aggregate. (*See table 8.*) Consumption increased 2%. Large gains were made in sales for civil engineering and sealing, construction (brick and cement), and refractory applications while those for lightweight aggregates lagged.

Fire Clay.—Fire clays were used in refractory products such as firebrick and block, grogs and calcines, high-alumina brick and specialties, saggers, refractory mortars and mixes, and ramming and gunning mixes. Fire clays also were used to produce such items as brick, ceramic tile, portland cement, and pottery.

Consumption of fire clay decreased 13%. Major markets for fire clay were firebrick, followed by refractory mortar and cement, common brick, grogs and calcines, ceramic tile, and pottery, in decreasing order of consumption. (*See table 10.*) Declining sales for the production of portland cement and grogs and calcines accounted for the bulk of the decrease in overall sales of fire clay.

Fuller's Earth.—The major uses for attapulgite-type and montmorillonite-type of the fuller's earths were as pet waste absorbents; pesticide carriers; and oil and grease absorbents, in decreasing order of consumption. (*See table 12.*) Overall consumption of fuller's earth decreased 2% in 1996. While sales of attapulgite-type fuller's earth increased, there was a slightly larger decrease in sales and use of montmorillonite-type fuller's earth.

Consumption declined slightly for the major end uses except pet waste absorbents. Oil and grease absorbents and pesticides accounted for most of the decrease.

With regard to the sales of attapulgite-type fuller's earth versus montmorillonite-type fuller's earth, most of the data were concealed to avoid disclosing company proprietary data. Less than one-half of the fuller's earth sold for oil and grease absorbents and pet waste absorbents was attapulgite. Attapulgite accounted for the bulk of the sales for miscellaneous absorbents, less than 25% of animal feed sales, more than 75% of the drilling mud sales, and most of the fertilizer sales. Over one-half of the fuller's earth used as pesticide carriers was montmorillonite.

Kaolin.—The major markets were in paper coating, paper filler, firebrick, fiber glass, catalyst, paint, common brick, rubber, and grogs and calcines, in decreasing order of consumption. (*See table 20.*) Consumption decreased 4% in 1996. The largest gains were made by the fiberglass market while the largest decline was in refractories, where major changes were occurring in several of the producing companies. Major domestic markets for kaolin from Georgia were paper coating, paper filling, refractories, fiberglass, and paint, in decreasing order of consumption. The major market for kaolin from South Carolina was brick manufacture, followed by rubber, catalyst, fiber glass, roofing granules, firebrick, adhesives, sanitaryware, pesticide, paper coating, paper filling, and plastics, in decreasing order of consumption. (*See tables 17 and 19.*)

Absorbent Uses.—Absorbent uses for clays accounted for about 2.54 million tons. Pet waste absorbents accounted for approximately 84% of absorbent consumption, followed by oil and grease absorbents (13%), and miscellaneous absorbent applications (3%). Demand for absorbents increased in 1996 corresponding to the growth in the pet litter market. Fuller's earth was the principal clay used for absorbent purposes,

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followed by bentonite. (*See tables 6 and 12.*)

The cat-litter market has contributed significantly to the increased sales of absorbents. Sales of bentonite and fuller's earth for cat-litter applications have increased worldwide. With increasing competition in the cat-litter market, specifications have become more important. Manufacturers must consider many factors when developing new products. Characteristics such as product density, absorption, granule size, odor control, dust formation, color, and material strength influence the choice of material for the product. The scoopable cat litters, composed primarily of sodium bentonite have increased significantly in popularity, accounting for about 30% of the market. Other clays used in cat litter include fuller's earth, sepiolite, attapulgite, and moler clays. Nonclay cat litters are composed of zeolites, gypsum, hydrated calcium silicate, and organic materials such as alfalfa pellets, peanut shells, and waste-paper pellets (Austin and Mojtabai, 1996).

Ceramics.—All varieties of clays were used in ceramics. Total demand for clay in the manufacture of ceramics, ranging from china to sanitaryware to tile to roofing granules, was approximately 1.62 million tons. The largest ceramics market was in ceramic floor and wall tile, followed by sanitaryware, catalyst, pottery, roofing granule, quarry tile, fine china, electrical porcelain, and glaze application. Ball clay accounted for 37% of the clay used in ceramics, followed by kaolin (31%) and common clay and shale (31%). Small amounts of bentonite, fire clay, and fuller's earth also were used in the manufacture of ceramics. With regard to individual ceramics markets, ball clay dominated the electrical porcelain, glazing, pottery, and sanitaryware markets. Common clay and shale was the predominant clay used in roofing granules. Kaolin dominated the catalyst, crockery, and fine china markets. Common clay and shale and ball clay were the predominant clays used in floor and wall tile manufacture. (*See tables 4, 8, 10, and 20.*)

Construction.—Common clays and shales were used to manufacture a wide variety of construction materials such as expanded aggregates, hydraulic cement, and structural clay products.

Expanded Clay and Shale.—Approximately 4.06 million tons of clays was used in the production of lightweight aggregate. Nearly all of the clay used to manufacture lightweight aggregate was common clay and shale. Lightweight aggregates were used in concrete block, structural concrete, and highway surfacing, in decreasing order of consumption. (*See tables 8 and 21.*)

Hydraulic Cement.—Clays provide the alumina and silica required to manufacture hydraulic cements. Approximately 7.20 million tons of clays was consumed. Common clays, kaolin, fuller's earth, and fire clay, in decreasing order of consumption, were used in cement products. Approximately 99% of the clay consumed by the cement industry was common clay and shale. (*See tables 8 and 20.*)

Metakaolin has been used in walls and roadway and bridge overlays on a limited scale since becoming available in 1994. The metakaolin is highly reactive and reacts with the cement's free lime. The metakaolin supposedly promotes low permeability, good compressive strength, and improved chemical resistance (Engineering News Record, 1996).

Structural Clay Products.—Approximately 14.0 million tons of clays was used in the manufacture of structural clay products such as building brick, drain tile, flue linings, roofing tile, sewer pipe, and terra cotta. Common and face brick accounted for 95% of this total. Other markets, in decreasing order of consumption, were sewer pipe, flue linings, flower pots, structural tile, roofing tile, drain tile, and terra cotta. Approximately 98% of the clay used in these applications was common clay and shale. (*See tables 8, 20, and 22.*)

The Bureau of the Census reported shipments of building and face brick to be 7.62 billion bricks valued at $1.24 billion. Shipments of clay floor and wall tile were 580 million square meters valued at $776 million. Shipments of vitrified clay and sewer pipe fittings were 138,000 tons valued at $36.2 million.

Drilling Mud.—Reported demand for clays in drilling muds was 611,000 tons. Swelling-type bentonite remained the principal clay used in drilling mud mixes (95%). Fuller's earth, used mostly in saltwater drilling techniques, accounted for 4% of the total. Some ball clay and kaolin also were used. (*See tables 6 and 12.*)

Filler.—Approximately 5.11 million tons of clays was used as fillers and extenders. Clays are used as binders, extenders, and fillers in a wide variety of products, ranging from adhesives to flooring products to paint to paper to rubber. Paper coating and filling accounted for 72% of the filler and extender market consumption, followed by paint (6%), pesticides (6%), animal feed (4%), and rubber (4%).

Kaolin accounted for approximately 86% of the clay used in filler and extender applications, followed by fuller's earth (9%), bentonite (2%), ball clay (2%), common clay and shale (1%), and minor amounts of fire clay. (*See tables 4, 6, 12, and 20.*) Ball clay dominated the asphalt emulsion market. Bentonite was the predominant clay used for ink applications. Fuller's earth was the predominant clays used in asphalt tile, fertilizer, gypsum product, and pesticide applications. Kaolin dominated the adhesive, linoleum, paint, paper, rubber, plastics, textile, and wallboard markets.

Glass.—Approximately 458,000 tons of kaolin was used in fiberglass and mineral wool. (*See table 20.*)

Iron Ore Pelletizing.—Demand increased to 685,000 tons in 1996. Almost all of the clay used in pelletizing was bentonite. (*See table 6.*) Small amounts of common clay and shale also were used.

Paper Products.—Kaolin accounted for essentially all of the clay used for paper coating (2.81 million tons) and all of the clay used for paper filling (854,000 tons). (*See table 20.*) Small amounts of ball clay were used in paper coating applications.

Refractories.—Approximately 2.60 million tons of clays was used for the manufacture of refractories. The largest markets were foundry sand (30%), firebrick (31%), high alumina specialties (26%), refractory mortar and cement (12%), grogs and calcines (9%), and high alumina brick (4%). Ball clay,

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bentonite, common clay and shale, fire clay, and kaolin accounted for 3%, 30%, 20%, 14%, and 33%, respectively, of the refractories markets. Fire clay dominated the high aluminum specialties market, bentonite dominated the foundry sand market, kaolin dominated the firebrick and grog, calcine, and high alumina brick markets, and common clay dominated the refractory mortar and cement market. (*See tables 4, 6, 8, 10, and 20.*)

The Bureau of the Census reported shipments of clay refractories to be valued at $944 million in 1996, a slight increase from 1995. Shipments of refractory brick and shapes were 815,000 tons (280 million bricks) valued at $559 million. Shipments of fire clay brick and shapes were 386,000 tons (128 million bricks) valued at $209 million in 1996; high alumina brick and shapes, 371,000 tons (100 million bricks) valued at $286 million; and insulating brick and shapes, 57,000 tons valued at $64 million. Shipments of unshaped clay refractories included refractory bonding mortars, 648,000 tons valued at $332 million and plastic refractories, 144,000 tons valued at $76.8 million. Shipments of castable refractories were 292,000 tons valued at $166 million. Shipments of fire clay gunning mixes were 164,000 tons valued at $61.7 million.

Prices

Ball Clay.—The average value for ball clay reported by domestic producers was $44.34 per ton. The average value of imported ball clay was $156.35. The average value of exported ball clay was $62.81 per ton.

Bentonite.—The average value reported by domestic producers for nonswelling bentonite was $47.57 per ton. The average value for swelling bentonite was $34.15 per ton. The average value for all types of bentonite was $35.80 per ton. The average value of imported bentonite was $271.06 per ton. The average value of exported bentonite was $102.38 per ton.

Common Clay and Shale.—The average value for all common clay and shale produced in the United States and Puerto Rico was $5.48 per ton. The average value of clay and shale used in lightweight aggregate was $12.11 per ton.

Fire Clay.—The average value for fire clay reported by domestic producers was $21.17 per ton. The average of imported fire clay was $456.77 per ton. The average value of exported fire clay was $102.60 per ton.

Fuller's Earth.—The average value of attapulgite-fuller's earth reported by domestic producers was $133.74 per ton. The average value of montmorillonite-fuller's earth was $93.11 per ton. The average value of all types of fuller's earth was $106.71 per ton. The average value of imported fuller's earth was $344.39 per ton. The average value of exported fuller's earth was $143.63 per ton.

Kaolin.—The average value of kaolin was $120.19 per ton for all kaolin grades. The average value for air-float kaolin was $54.68 per ton; for high-temperature calcined kaolin, $18.88;per ton for low-temperature calcined kaolin, $411.50 per ton; for all types of calcined kaolin, $185.79 per ton; for delaminated kaolin, $125.79 per ton; for water-washed kaolin, $120.92 per ton; and for unprocessed kaolin, $18.74 per ton. The average value of the imported kaolin was $239.14 per ton. The average value of exported kaolin was $172.27 per ton.

Foreign Trade

Ball Clay.—Ball clay exports decreased 80,000 tons valued at $5.27 million, according to the Bureau of the Census. (*See table 23.*) Domestic ball clay producers reported that 129,000 tons of ball clay was exported in 1996. The exports were used mainly for floor and wall tile production and sanitaryware production. Other major uses are asphalt emulsions, china, dinnerware, and filler and extender applications.

Discrepancies were observed between the export tonnage reported by the Bureau of the Census and that reported by producers. One reason is that the producers may not control the final sale and movement of the clays, as when a mineral broker is involved. Some clays originally destined for export may be sold domestically and vice-versa without the knowledge of the producer. Another reason is that some clay may be exported under an export code other than that corresponding to ball clay. In 1996 imports were 1,400 tons of ball clay valued at $337,000. (*See table 24.*)

Bentonite.—Bentonite exports increased slightly to 746,000 tons valued at $80.6 million. Domestic bentonite producers reported exports of 426,000 tons. This discrepancy is partially explained by the inclusion of an estimated 100,000 tons of bentonite for Canadian iron ore pelletizing under domestic sales. Also see the discussion under ball clay concerning discrepancies between export data reported by producers and those reported by the Bureau of the Census. (*See tables 6 and 23.*)

Bentonite imports consisted mainly of untreated bentonite clay and chemically or artificially activated materials. Imports of untreated bentonite were 7,510 tons valued at $1,760,000. Imports of chemically activated material were 18,600 tons valued at $11.0 million. (*See table 24.*)

Fire Clay.—Exports of fire clay were 295,000 tons valued at $28.5 million. According to the Bureau of the Census, 355 tons valued at $230,000 was imported in 1996. (*See tables 23 and 24.*)

Fuller's Earth.—Approximately 112,000 tons of fuller's earth valued at $13.2 million were exported. Domestic producers reported more than 164,000 tons exports in 1996. Discrepancies between producers' and Bureau of the Census reports for exports are similar to the situation with ball clay. Also, some of the exports reported by producers may have been classified as pet litter by the Bureau of the Census rather than as fuller's earth. (*See table 12.*) Approximately 368 tons of decolorizing and fuller's earth valued at $159,000 were imported in 1996. (*See tables 12, 23, and 24.*)

Kaolin.—The Bureau of the Census reported that 3.24 million tons of kaolin valued at $555 million were exported in 1996. Producers reported exports of 2.43 million tons. Discrepancies between producers' and Bureau of the Census

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reports for exports are similar to the situation with ball clay. (*See tables 20 and 23.*) Kaolin imports increased to 13,700 tons valued at $5.84 million. (*See table 24.*)

World Review

World production of bentonite was 9.19 million tons, fuller's earth production was 3.66 million tons, and kaolin production was 38.6 million tons. The United States continued to be the leading producer of all three clay types, followed by the former Soviet Union for bentonite, Germany for fuller's earth, and Uzbekistan for kaolin. Spain led all countries in the production of sepiolite. (*See tables 25, 26, and 27.*)

Australia.—Comalco announced plans to close its kaolin operations in Queensland. The current production rate of 11,000 tons per year was not adequate to remain economical viable (Tait, 1996).

Brazil.—Dry Branch Kaolin Co. (DBK), based in Dry Branch, GA, increased its holdings in Rio Capim Caulim to 49%. DBK had acquired a 24.5% share of Rio Capim in late 1995. The company has invested about $110 million and equipment in the project, which was scheduled to begin operations in mid-1996 (Industrial Minerals, 1996d).

Caulim Da Amazonia S.A. completed a $47.9 million expansion of its facilities, increasing its capacity to 800,000 tons per year. The company also announced plans for further expansion to 1 million tons per year at a cost of $29 million (Industrial Minerals, 1996b).

Canada.—A large kaolinitic clay and silica sand deposit in Nova Scotia was investigated by the Department of Natural Resources. The deposit consists of layers of white to red kaolinitic clay, massive gray kaolin with pyrite, gray kaolinitic silica sand, and black organic-rich kaolinitic clay. Brightnesses of 91.2% were achieved through calcining (North American Minerals News, 1996c).

India.—American Colloid Co. entered into a joint venture with Ashapura Minechem Ltd. to mine bentonite in Gujarat. American Colloid owns 49% of the shares. The companies initially plan to limit their market to cat litter and activated fuller's earth. The operation eventually will be expanded to include such products as geosynthetic liners, organophillic clays, speciality binders, and animal feed (Industrial Minerals, 1996a).

Indonesia.—Watts, Blake, and Bearne Group (WBB) formed a joint venture with WBB subsidiary Pacific Clays Pte. Ltd. and PT Clayindo Cakra Jaya (CCJ) to produce blended ball clay products. The new company, called WBB Clayindo, has taken over the operations of CCJ at Capkala and new clay blending, noodling, and storage facilities are being developed. Initially, the company will supply ball clay to the Indonesian ceramics industry (The American Ceramic Society Bulletin, 1996).

Thailand.—ECC International announced a joint venture with Banpu Co. Ltd. The new company, MRD-ECC Co. Ltd., will mine ball clay deposits in northern Thailand and kaolin from southern Thailand. Production will be 100,000 tons per year with most going into the ceramics markets (ECC International, 1996).

Ukraine.—Dnipro Kaolin, a joint venture between Engelhard Co. and Prosyanoye Mining and Enrichment Combine of the Ukraine, will mine and sell kaolin to the European paper and paperboard industry. The company will produce 100,000 tons per year and anticipates adding calcined products in the future (Chemical Week, 1996a).

United Kingdom.—Tolsa SA acquired the bentonite and absorbents portion of Redland Minerals. The new company, Steetley Bentonite and Absorbents Ltd., will promote its cat litters as well as other industrial products. Mining and processing will continue at the company's Bedfordshire, South Humberside, and Cleveland locations (Industrial Minerals, 1996f).

Outlook

U.S. clay demand between 1982 and 1996 has rebounded slowly from 32 million tons to 43 million tons. Fueling the increase are the generally improved building and construction industry (for brick, cement, ceramics, etc.), growing paper industry (paper coating and filler), growth in the pet litter market (pet waste absorbents), and concerns over seepage from landfills and waste dumps (civil engineering and sealing applications). Most of these markets can be expected to grow over the next few years.

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TABLE 1
SALIENT U.S. CLAY STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
Domestic clays sold or used by producers:					
Quantity	40,200	40,700	42,000	43,100	43,100
Value	$1,470,000	$1,470,000	$1,590,000	$1,730,000	$1,710,000
Exports:					
Quantity	4,160	4,150	4,620	4,680	4,830
Value	$663,000	$670,000	$739,000	$812,000	$825,000
Imports for consumption:					
Quantity	41	39	36	35	45
Value	$15,500	$17,600	$14,900	$16,000	$21,000

1/ Excludes Puerto Rico.
2/ Data are rounded to three significant digits.

TABLE 2
CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	166	2,290	52	--	254	2,760	25,000
Arizona	--	W	104	--	--	--	104	W
Arkansas	--	--	939	W	--	161	1,100	2,390
California	--	148	1,340	60	224	W	1,770	26,500
Colorado	--	1	317	--	--	6	324	2,340
Connecticut	--	--	W	--	--	--	W	W
Florida	--	--	W	--	377	35	412	62,600
Georgia	--	--	1,660	--	739	8,040	10,400	1,150,000
Illinois	--	--	155	--	330	--	486	736
Indiana	38	--	1,510	--	--	--	1,550	3,500
Iowa	--	--	478	--	--	--	478	1,180
Kansas	--	--	548	--	64	--	611	2,250
Kentucky	70	--	823	--	--	--	893	3,680
Louisiana	--	--	382	--	--	--	382	548
Maine	--	--	W	--	--	--	W	W
Maryland	--	--	304	--	--	--	304	874
Massachusetts	--	--	W	--	--	--	W	W
Michigan	--	--	652	--	--	--	652	3,410
Minnesota	--	--	11	--	--	--	11	W
Mississippi	73	145	534	--	379	--	1,130	40,500
Missouri	13	--	849	223	283	--	1,370	6,470
Montana	--	W	34	W	--	--	34	W
Nebraska	--	--	277	--	--	--	277	1,140
Nevada	--	6	--	--	W	25	31	580
New Hampshire	--	--	3	--	--	--	3	16
New Jersey	--	--	74	--	--	--	74	125
New Mexico	--	--	32	W	--	--	32	165
New York	--	--	652	--	--	--	652	14,000
North Carolina	--	--	2,400	--	--	W	2,400	12,400
North Dakota	--	--	59	--	--	--	59	W
Ohio	--	--	1,960	103	--	--	2,060	10,700
Oklahoma	--	--	799	23	--	--	822	4,090
Oregon	--	33	213	--	--	--	247	1,690
Pennsylvania	--	--	753	--	--	14	767	3,230
South Carolina	--	--	1,260	24	--	387	1,670	23,000
South Dakota	--	--	147	--	--	--	147	W
Tennessee	679	--	W	--	W	32	710	29,000
Texas	101	--	2,290	--	W	28	2,420	15,000
Utah	--	W	298	--	W	--	334	5,940
Virginia	--	--	883	--	46	--	929	3,220
Washington	--	--	218	--	--	--	218	1,070
West Virginia	--	--	199	--	--	--	199	369
Wyoming	--	3,030	29	--	--	--	3,060	98,400
Total	973	3,740	26,200	505	2,600	9,120	43,100	1,710,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Excludes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 3
BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Airfloat		Water-slurried		Unprocessed		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1995:								
Tennessee	291	15,600	156	6,930	217	6,410	663	29,000
Other 2/	192	10,700	(3/)	(3/)	137	5,830	329	16,600
Total	483	26,300	156	6,930	354	12,200	993	45,500
1996:								
Tennessee	255	13,900	187	8,270	236	6,870	679	29,000
Other 2/	155	8,240	(3/)	(3/)	139	5,920	294	14,200
Total	411	22,100	187	8,270	375	12,800	973	43,100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes Indiana, Kentucky, Mississippi, Missouri (1996), and Texas.
3/ Included with "Unprocessed."

TABLE 4
BALL CLAY SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Filler, extenders, and binders 2/	114,000	109,000
Floor and wall tile	251,000	223,000
Miscellaneous ceramics 3/	62,200	45,500
Pottery	128,000	118,000
Refractories 4/	70,800	78,900
Sanitaryware	208,000	207,000
Miscellaneous 5/	48,900	63,500
Exports 6/	110,000	129,000
Total	993,000	973,000

1/ Data are rounded to three significant digits, may not add to totals shown.
2/ Includes adhesives, animal feed, asphalt emulsions, paper, pesticides, plastics, rubber, and other filler, extenders and binders.
3/ Includes crockery, electrical porcelain, fine china/dinnerware, glazes, and miscellaneous ceramics.
4/ Includes firebrick, blocks, and shape, high-alumina brick and specialties, and miscellaneous refractories.
5/ Includes absorbents, brick (common), flue lining, glazes, waterproofing seals, drilling mud, and other uses unknown.
6/ Includes ceramics and glass, fillers, extenders and binders, floor and wall tile, and other uses unknown.

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TABLE 5
BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Nonswelling		Swelling		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1995:						
California	W	W	W	W	149	14,000
Colorado	(2/)	9	--	--	(2/)	9
Mississippi	164	6,510	--	--	164	6,510
Nevada	W	W	W	W	6	477
Oregon	W	W	W	W	17	917
Wyoming	--	--	2,940	89,900	2,940	89,900
Other 3/	216	10,000	324	16,300	540	26,300
Total	510	27,600	3,310	111,000	3,820	138,000
1996:						
California	W	W	W	W	148	13,900
Colorado	1	19	--	--	1	19
Mississippi	145	4,480	--	--	145	4,480
Nevada	W	W	W	W	6	580
Oregon	W	W	W	W	33	1,530
Wyoming	--	--	3,030	9,850	3,030	9,850
Other 3/	315	17,400	251	102,000	566	120,000
Total	461	21,900	3,280	112,000	3,740	134,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes Alabama, Arizona, Montana, Texas, and Utah.

TABLE 6
BENTONITE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Domestic:		
Absorbents:		
Pet waste absorbents	574,000	607,000
Other absorbents	88,400	90,500
Adhesives	W	11,200
Animal feed	97,800	65,200
Ceramics (except refractories) 2/	W	W
Drilling mud	627,000	572,000
Filler and extender applications 3/	69,900	33,500
Filtering, clarifying, decolorizing: Animal oils, minerals oils and greases, and vegetable oils	W	W
Foundry sand	745,000	772,000
Pelletizing (iron ore)	646,000	674,000
Miscellaneous refractories and kiln furniture 4/	21,800 r/	16,700
Miscellaneous 5/	288,000	242,000
Waterproofing and sealing	228,000	227,000
Total	3,390,000	3,310,000
Exports:		
Drilling mud	86,500	102,000
Foundry sand	256,000	278,000
Other 6/	89,100	46,400
Total	431,000	426,000
Grand total	3,820,000	3,740,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes floor and wall tile, and pottery.
3/ Includes medical, pharmaceutical, and cosmetics, paint, pesticides and related products, plastics, asphalt emulsions, ink, and miscellaneous fillers and extenders applications.
4/ Includes kiln furniture, plugs, taps, wads, and miscellaneous refractories.
5/ Includes chemical manufacturing, filtering and clarifying oils, heavy clay products, and other uses unknown.
6/ Includes absorbents, waterproofing and sealing, fillers and extenders, and pelletizing refactories.

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TABLE 7
COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1995		1996	
	Quantity	Value	Quantity	Value
Alabama	2,080	18,600	2,290	17,100
Arkansas	973	2,920	939	2,390
California	1,430	14,500	1,340	12,600
Georgia	1,660	11,200	1,660	11,200
Indiana	877	3,350	1,510	3,500
Kansas	573	2,390	548	2,250
Kentucky	786	3,430	823	3,680
Michigan	623	3,430	652	3,410
Mississippi	616	6,080	534	3,610
Missouri	972	4,810	849	3,250
New York	563	12,500	652	14,000
North Carolina	2,430	12,500	2,400	12,400
Ohio	1,840	7,560	1,960	7,450
Oklahoma	674	3,580	799	4,090
Pennsylvania	736	2,430	753	2,420
South Carolina	1,220	4,910	1,260	4,860
Texas	2,320	15,500	2,290	15,000
Virginia	844	3,200	883	3,220
Other 3/	4,350	18,300	4,060	17,500
Total	25,600	151,000	26,200	144,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes Puerto Rico.
3/ Includes all other States except; Alaska, Delaware, Hawaii, Idado, Nevada, Rhode Island, Vermont, and Wisconsin.

TABLE 8
COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/ 2/

(Metric tons)

Use	1995	1996
Ceramics and glass 3/	139,000	142,000
Civil engineering and sealing	180,000	279,000
Floor and wall tile:		
Ceramic	301,000	293,000
Other 4/	73,000	61,900
Heavy clay products:		
Brick, extruded	11,200,000	11,300,000
Brick, other	1,640,000	1,730,000
Drain tile and sewer pipe	136,000	123,000
Flowerpots	48,600	47,400
Flue linings	59,800	45,200
Structural tile	21,500	21,500
Other 5/	503,000	505,000
Lightweight aggregate:		
Concrete block	2,530,000	2,450,000
Highway surfacing	248,000	245,000
Structural concrete	869,000	887,000
Miscellaneous 6/	521,000	471,000
Portland and other cements	6,400,000	7,000,000
Refractories 7/	459,000	519,000
Miscellaneous 8/	268,000	117,000
Total	25,600,000	26,200,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes Puerto Rico.
3/ Includes pottery and roofing granules.
4/ Includes quarry tile and miscellaneous floor and wall tiles.
5/ Includes roofing tile, sewer pipe, and miscellaneous clay products.
6/ Includes miscellaneous lightweight aggregates.
7/ Includes firebrick, blocks and shapes, grogs and calcines, mortar and cement, and miscellaneous refractories.
8/ Includes asphalt emulsions, pelletizing (iron ore), exports, and other uses unknown.

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TABLE 9
FIRE CLAY SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1995		1996	
	Quantity	Value	Quantity	Value
Alabama	80	3,120	52	2,800
Missouri	359	5,480	223	3,220
Ohio	88	3,140	103	3,230
Other 3/	56	1,060	127	1,450
Total	583	12,800	505	10,700

1/ Refractory uses only.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes Arkansas, California, Montana, New Mexico, Oklahoma (1996), and South Carolina.

TABLE 10
FIRE CLAY SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Ceramics and glass 2/	W	W
Heavy clay products and lightweight aggregates 3/	104,000	78,800
Refractories:		
Firebrick, block and shapes	168,000	166,000
Other refractories 4/	232,000	188,000
Miscellaneous	78,400	72,800
Exports	--	W
Total	583,000	505,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes pottery.
3/ Includes portland cement, terra cotta, and other uses unknown.
4/ Includes common brick, flue linings, foundry sand, grogs and calcines, mortar and cement, plug, tap and wad, and other uses unknown.

TABLE 11
FULLER'S EARTH SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Attapulgite		Montmorillonite		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1995:						
Florida	388	50,800	(2/)	(2/)	388	50,800
Georgia	744	90,100	(2/)	(2/)	744	90,100
Southern States 3/	--	--	542	37,800	542	37,800
Western States 4/	(5/)	(5/)	964	89,900	964	89,900
Total	1,130	141,000	1,510	128,000	2,640	269,000
1996:						
Florida	377	58,900	(2/)	(2/)	377	58,900
Georgia	739	89,200	(2/)	(2/)	739	89,200
Southern States 3/	--	--	504	38,500	504	38,500
Western States 4/	(5/)	(5/)	981	91,100	981	91,100
Total	1,120	148,000	1,490	130,000	2,600	278,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Included with "Attapulgite."
3/ Includes Mississippi, Tennessee, and Virginia.
4/ Includes California, Illinois, Kansas, Missouri, Nevada, Texas, and Utah (1996).

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TABLE 12
FULLER'S EARTH SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Absorbents:		
Oil and grease absorbent	285,000	258,000
Pet waste absorbent	1,530,000	1,530,000
Miscellaneous absorbent	W	W
Animal feed	72,700	89,600
Drilling mud	23,200	24,000
Fertilizers	50,800	48,900
Fillers, extenders, binders 2/	75,000	76,600
Filtering, clarifying, decolorizing: Animal, mineral, and vegetable oils, and greases	9,070	8,170
Pesticides and related products	302,000	261,000
Miscellaneous 3/	130,000	145,000
Exports 4/	161,000	164,000
Total	2,640,000	2,600,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes adhesives, asphalt tiles, gypsum products, medical, pharmaceutical and cosmetics, paint, plastics, asphalt emulsions, textiles, and other uses unknown.
3/ Includes catalysts (oil-refining), electrical porcelain, roofing granules, chemical manufacturing, portland cement, refractories, and other uses unknown.
4/ Includes absorbents, fillers, extenders and binders, floor and wall tiles, refractories, and other uses unknown.

TABLE 13
KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

	1995		1996	
State	Quantity	Value	Quantity	Value
Arkansas	182	4,890	161	W
Florida	33	3,510	35	3,760
Georgia	8,240	1,060,000	8,040	1,050,000
South Carolina	373	16,800	387	18,100
Other 2/	657	23,700	496	23,400
Total	9,480	1,110,000	9,120	1,100,000

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes Alabama, California, Colorado, Minnesota, Nevada, North Carolina, Pennsylvania, Tennessee, Texas, and items indicated by symbol W.

TABLE 14
KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY KIND 1/

(Thousand metric tons and thousand dollars)

	1995		1996	
Kind	Quantity	Value	Quantity	Value
Airfloat	1,240	68,500	1,150	62,900
Calcined 2/	1,850	296,000	1,670	309,000
Delaminated	1,570	187,000	1,520	191,000
Unprocessed	457	10,400	450	8,430
Water-washed	4,380	547,000	4,340	525,000
Total	9,480	1,110,000	9,120	1,100,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes both low-temperature filler and high-temperature refractory grades.

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TABLE 15
CALCINED KAOLIN SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	High-temperature		Low-temperature	
	Quantity	Value	Quantity	Value
1995:				
Alabama and Georgia	1,090	55,300	542	226,000
Other 2/	112	6,140	105	8,880
Total	1,200	61,400	648	235,000
1996:				
Alabama and Georgia	858	13,900	670	285,000
Other 2/	99	4,190	38	6,580
Total	957	18,100	708	291,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes Arkansas, California, Colorado, Pennsylvania, South Carolina, and Texas.

TABLE 16
GEORGIA KAOLIN SOLD OR USED
BY PRODUCERS, BY KIND 1/

(Thousand metric tons and thousand dollars)

Kind	1995		1996	
	Quantity	Value	Quantity	Value
Airfloat	953	47,700	832	38,300
Calcined 2/	1,260	274,000	1,270	293,000
Delaminated	1,540	187,000	1,500	191,000
Unprocessed	154	6,250	133	5,220
Water-washed	4,330	545,000	4,300	523,000
Total	8,240	1,060,000	8,040	1,050,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes both low-temperature filler and high-temperature refractory grades.

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TABLE 17
GEORGIA KAOLIN SOLD OR USED BY PRODUCERS, BY USE 1/ 2/

(Metric tons)

Use	1995	1996
Domestic:		
Ceramics and glass:		
Catalysts (oil-refining)	W	W
Electrical porcelain	W	5,930
Fiber glass	292,000	418,000
Roofing granules	13,800	9,660
Sanitaryware	60,000	64,200
Other 3/	213,000	234,000
Fillers, extenders, and binder:		
Adhesives	61,500	78,400
Paint	267,000	262,000
Paper coating	2,790,000	2,800,000
Paper filling	846,000	847,000
Plastic	36,900	31,000
Rubber	103,000	112,000
Other 4/	117,000	86,500
Heavy clay products 5/	21,800	20,900
Refractories 6/	677,000	523,000
Undistributed 7/	262,000	150,000
Total	5,760,000	5,650,000
Exports:		
Paint	67,700	66,300
Paper coating	2,040,000	2,000,000
Paper filling	145,000	142,000
Rubber	17,700	8,570
Undistributed 8/	209,000	185,000
Total	2,480,000	2,400,000
Grand total	8,240,000	8,040,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."

1/ Includes high-temperature calcined, low-temperature calcined, and delaminated.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes crockery/earthenware, fine china/dinnerware, glazes, glass, and enamels, pottery, and miscellaneous ceramics.

4/ Includes asphalt emulsion, asphalt tile, fertilizers, gypsum products, medical, pharmaceutical and cosmetics, pesticides and related products, textiles and miscellaneous fillers, extenders and binders, and ink.

5/ Includes brick (common and face), portland cement, and miscellaneous clay products.

6/ Includes firebrick, blocks and shapes, grogs and calcines, high-alumina specialties, kiln furniture, and miscellaneous refractories.

7/ Includes chemical manufacturing, civil engineering and sealings, drilling mud, filtering, clarifying, and decolorizing, floor and wall tiles, pet waste absorbents, and other uses unknown.

8/ Includes fiber glass, sanitaryware, ink, miscellaneous fillers, extenders and binders, and other uses unknown.

TABLE 18
SOUTH CAROLINA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND 1/

(Thousand metric tons and thousand dollars)

	1995		1996	
Kind	Quantity	Value	Quantity	Value
Airfloat	219	14,900	220	16,600
Unprocessed 2/	153	1,870	167	1,460
Total	373	16,800	387	18,100

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes high-temperature and low-temperature calcined and delaminated.

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TABLE 19
SOUTH CAROLINA KAOLIN SOLD OR USED
BY PRODUCERS, BY KIND AND USE 1/

(Metric tons)

Kind and use	1995	1996
Adhesives	W	W
Animal feed and pet waste absorbent	W	W
Ceramics 2/	90,100 r/	93,600
Fertilizers, pesticides and related products	5,140	5,220
Fiber glass	W	W
Paper coating and filling	8,290	8,290
Plastics	W	W
Rubber	91,100	79,300
Refractories 3/	W	10,200
Other uses 4/	159,000 r/	172,000
Exports 5/	18,700	18,500
Total	373,000	387,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other uses."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes crockery and earthenware, fine china/dinnerware, floor and wall tile, pottery, and roofing granules.

3/ Includes refractory calcines and grogs, firebrick, blocks and shapes, refractory mortar and cement, and high-alumina refractories.

4/ Includes brick (face and common), catalysts (oil refining), asphalt emulsion, gypsum products, and unknown uses.

5/ Includes paint, paper filling, and rubber.

TABLE 20
KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Domestic:		
Ceramics:		
Catalyst (oil and gas refining)	213,000 r/	212,000
Electrical porcelain	7,600	12,300
Fine china and dinnerware	26,400	26,400
Floor and wall tile	38,300	31,800
Pottery	20,600	25,700
Roofing granules	24,900	21,300
Sanitaryware	67,900	72,100
Miscellaneous	152,000	100,000
Chemical manufacture	130,000	W
Civil engineering	W	7,780
Glass fiber, mineral wool	402,000	458,000
Filler, extender, and binder:		
Adhesive	71,600	88,100
Fertilizer	W	W
Medical, pharmaceutical cosmetic	W	W
Paint	270,000	288,000
Paper coating	2,800,000	2,810,000
Paper filling	853,000	854,000
Pesticide	11,200	16,700
Plastic	39,500	36,300
Rubber	194,000	191,000
Miscellaneous	155,000 r/	93,300
Heavy clay products:		
Brick, common and face	230,000	214,000
Portland cement	W	W
Refractories:		
Firebrick, block and shapes	26,800	565,000
Grogs and calcines	190,000	173,000
High alumina brick, specialties, and kiln furniture	885,000	86,800
Foundry sand, mortar, cement, and miscellaneous refractories	145,000	78,000
Miscellaneous applications	19,900 r/	231,000
Total	6,970,000	6,690,000

See footnotes at end of table.

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TABLE 20--Continued
KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Metric tons)

Use	1995	1996
Exports:		
Ceramics	187,000	179,000
Foundry sand, grogs and calcines; other refractories	20,700	W
Paint	67,700	66,300
Paper coating	2,040,000	2,000,000
Paper filling	145,000	142,000
Rubber	36,300	26,900
Miscellaneous	20,900	19,900
Total	2,510,000	2,430,000
Grand total	9,480,000	9,120,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous" or "Miscellaneous applications."

1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 21
COMMON CLAY AND SHALE USED IN LIGHTWEIGHT AGGREGATE PRODUCTION IN THE UNITED STATES BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Concrete block	Structural concrete	Highway surfacing	Other	Total	Total value e/
1995:						
Alabama and Arkansas	857	115	23	72	1,070	14,200
California	141	104	--	76	321	7,540
Florida and Indiana	153	36	--	60	249	1,650
Kansas, Kentucky, Louisiana	295	128	--	95	518	1,180
Mississippi and Missouri	15	1	2	126	145	1,690
New York and Montana	238	201	--	--	440	11,700
North Carolina	301	52	--	8	361	4,050
Ohio, Oklahoma, Pennsylvania	187	26	--	(2/)	214	1,430
Texas	49	157	222	31	459	2,520
Utah and Virginia	298	48	1	52	399	4,570
Total	2,530	869	248	521	4,170	50,500
1996:						
Alabama and Arkansas	792	103	21	67	983	13,200
California	141	104	--	76	321	7,540
Florida and Indiana	153	36	--	60	249	1,650
Kansas, Kentucky, Louisiana	295	128	--	86	509	1,180
Mississippi and Missouri	15	1	2	116	134	1,560
New York and Montana	265	235	--	--	500	13,200
North Carolina	301	52	--	--	353	4,050
Ohio, Oklahoma, Pennsylvania	187	26	--	--	213	1,430
Texas	49	157	222	31	459	2,520
Utah and Virginia	255	45	--	35	335	4,850
Total	2,450	887	245	471	4,060	51,200

e/ Estimated.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

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TABLE 22
COMMON CLAY AND SHALE USED IN BUILDING BRICK
PRODUCTION IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

State	1995		1996	
	Quantity	Value	Quantity	Value
Alabama	646	2,690	860	2,160
Arkansas	449	893	448	375
California	318	1,460	288	1,390
Colorado	261	1,930	295	2,190
Connecticut, New Jersey, 3/ New York 3/	280	1,160	287	1,370
Georgia	1,210	8,920	1,250	8,950
Illinois	469	685	128	634
Indiana and Iowa	364	1,720	383	1,180
Kentucky 3/ and Tennessee 3/	752	2,030	760	2,080
Maryland and West Virginia 4/	264	817	277	706
Mississippi and Missouri	521	2,010	541	2,210
North Carolina	1,990	7,370	1,970	7,310
Ohio	874	4,140	835	3,990
Oklahoma	330	1,790	445	2,260
Pennsylvania	602	1,790	654	2,140
South Carolina	789	3,450	819	3,290
Texas	1,090	7,090	1,120	7,840
Virginia	632	2,010	671	2,030
Other 5/	948	3,910	966	3,860
Total	12,800	55,900	13,000	56,000

1/ Includes extruded and other brick.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Extruded brick only.
4/ Includes other brick only.
5/ Includes Arizona, Maine, Minnesota, New Mexico, North Dakota, and Wyoming.

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TABLE 23
U.S. EXPORTS OF CLAYS IN 1996, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	(2/)	3	(2/)	252	(2/)	3	--	--
Australia	--	--	2	696	27	2,720	(2/)	17
Belgium	--	--	3	1,010	(2/)	7	(2/)	47
Brazil	1	21	10	2,040	(2/)	105	(2/)	11
Canada	--	--	191	13,600	5	1,010	71	6,020
Finland	1	81	2	200	--	--	(2/)	18
France	2	53	54	2,990	(2/)	61	(2/)	16
Germany	(2/)	9	22	2,050	(2/)	79	1	110
Indonesia	(2/)	8	5	1,080	2	190	1	75
Italy	(2/)	8	2	710	--	--	3	690
Japan	1	97	147	13,100	37	3,940	1	61
Korea, Republic of	(2/)	22	14	4,970	5	1,180	(2/)	16
Malaysia	--	--	20	1,360	--	--	9	1,250
Mexico	42	2,630	21	2,340	84	6,410	1	173
Netherlands	(2/)	34	14	2,300	113	10,100	10	1,220
Singapore	2	27	3	1,040	(2/)	11	1	167
South Africa	(2/)	3	1	206	(2/)	78	2	351
Taiwan	9	652	23	3,190	10	676	(2/)	14
Thailand	--	--	26	2,830	--	--	(2/)	10
United Kingdom	(2/)	19	83	7,160	1	135	1	461
Venezuela	12	871	29	2,970	(2/)	162	1	184
Other	10	732	74	14,400	11	1,620	10	2,260
Total	80	5,270	746	80,600	295	28,500	112	13,200

	Kaolin		Clays, n.e.c. 3/		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	17	3,930	2	979	20	5,160
Australia	17	9,270	5	2,920	52	15,600
Belgium	29	10,200	4	5,890	36	17,100
Brazil	13	3,120	2	2,200	26	7,500
Canada	601	77,600	186	32,300	1,050	131,000
Finland	358	53,300	1	217	361	53,800
France	6	1,290	4	1,820	65	6,230
Germany	35	10,500	9	4,270	67	17,000
Indonesia	51	10,400	1	1,540	59	13,300
Italy	167	26,500	1	1,000	173	28,900
Japan	854	165,000	19	12,700	1,060	195,000
Korea, Republic of	162	26,700	6	5,740	188	38,600
Malaysia	3	727	1	1,050	33	4,390
Mexico	149	15,300	12	4,390	308	31,200
Netherlands	305	41,100	15	9,340	458	64,100
Singapore	3	737	3	3,130	12	5,110
South Africa	15	4,420	3	1,520	21	6,580
Taiwan	136	19,600	5	2,560	184	26,700
Thailand	24	5,670	2	1,770	52	10,300
United Kingdom	46	4,920	27	19,600	158	32,300
Venezuela	21	4,290	9	2,700	72	11,200
Other	223	61,000	47	24,600	374	105,000
Total	3,240	555,000	364	142,000	4,830	825,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Also includes chamotte or dinas earth, activated clays and earths, and artificially activated clays.

Source: Bureau of the Census.

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TABLE 24
U.S. IMPORTS FOR CONSUMPTION OF CLAY IN 1996, BY KIND 1/

Kind	Quantity (metric tons)	Value (thousands)
China clay or kaolin:		
Brazil	502	$107
China	499	235
Mexico	4,370	1,650
New Zealand	1,470	929
United Kingdom	6,500	2,680
Other	394	236
Total	13,700	5,840
Fire clay:		
Spain	64	61
United Kingdom	288	161
Other	3	7
Total	355	230
Decolorizing earths and fuller's earth:		
China	16	5
France	352	154
Total	368	159
Bentonite:		
Canada	3,060	594
Japan	766	87
Mexico	2,260	260
United Kingdom	1,230	663
Other	203	153
Total	7,510	1,760
Common blue clay and other ball clay:		
Germany	321	72
Mexico	15	4
United Kingdom	1,060	261
Total	1,400	337
Other clay:		
Canada	622	230
Germany	136	137
Netherlands	101	44
South Africa	195	236
United Kingdom	1,310	734
Other	154	217
Total	2,520	1,600
Chamotte or dina's earth:		
Brazil	3	5
Canada	36	32
Total	39	37
Artificially activated clay and activated earth:		
Austria	555	732
Canada	1,580	1,220
Germany	1,660	2,500
Mexico	14,000	5,200
Other	820	1,350
Total	18,600	11,000
Grand total	44,600	21,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 25
BENTONITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria 4/	31,019	20,833	20,215	20,000 e/	20,000
Argentina	97,531	96,706	117,095 r/	113,760 r/	110,000
Armenia e/	50	50	100	110 5/	2,750 5/
Australia e/ 4/	35,000	35,000	35,000	35,000	35,000
Bosnia and Herzegovina e/	1,000	800	800	800	800
Brazil (beneficiated)	131,180	113,215	145,000 r/	130,000 r/	130,000
Bulgaria	75,000 e/	78,000	76,300	125,800	118,212 5/
Burma	693	200	795	2,655 r/	2,600
Chile	1,081	989	1,213 r/	1,000 r/ e/	1,000
Croatia	10,000 e/	10,000 e/	10,391 r/	7,327 r/	9,728 5/
Cyprus	58,840	51,689	46,530	50,000 e/	50,000
Egypt	4,215	6,013	2,379	2,500 e/	3,000
France e/	6,000 5/	6,000	7,000	-- r/	--
Germany	581,169	473,102	475,000 e/	500,000 e/	500,000
Greece	600,083	677,578	697,773	1,115,119 r/	1,000,000
Guatemala e/	12,600	12,300	4,408 5/	4,500 r/	4,500
Hungary	23,000	9,404	14,700	22,792 r/	15,376 5/
Indonesia	17,960	13,707	14,409	26,057	26,000
Iran 6/	47,659	85,000	84,000	85,000 e/	85,000
Italy	150,503	327,000	386,000	402,000 r/	400,000
Japan	534,472	517,389	484,115	478,056 r/	468,728 5/
Macedonia e/	40,000	35,000	30,000	30,000	30,000
Mexico	135,993	94,600	100,000 e/	72,599 r/	72,600
Morocco	8,137	10,811	24,919	29,308 r/	29,881 5/
Mozambique	20	100 e/	3,349	3,000 e/	3,000
New Zealand (processed)	--	1,613	930 r/	3,699 r/	3,500
Pakistan	6,057	7,991	11,180	5,759	15,290 5/
Peru	14,210	10,250	27,682	26,961 r/	18,592 5/
Philippines	7,428	5,050	25,000 e/	20,000 e/	20,000
Poland	20,700 r/	19,800 r/	19,900 r/	20,000 e/	20,000
Romania	100,000 r/ e/	50,000 r/ e/	41,056 r/	42,277 r/	43,540 5/
Serbia and Montenegro	200 r/	110 r/	215 r/	192 r/	95 5/
South Africa 7/	43,977	50,441	71,773	70,927	48,076 5/
Spain	157,301 r/	162,405 r/	179,233 r/	143,794 r/	150,000
Tanzania e/	70	70	70	70	70
Turkey	123,516	456,597	516,187	602,499 r/	600,000
Turkmenistan e/	50,000	50,000	50,000	50,000	50,000
U.S.S.R. e/ 8/	2,000,000	1,600,000	1,300,000	1,300,000	1,200,000
United States	2,950,000	2,870,000	3,290,000	3,820,000	3,740,000 5/
Zimbabwe 7/	82,956	83,000 e/	169,097	169,487 r/	165,509 5/
Total	8,160,000 r/	8,040,000 r/	8,480,000 r/	9,530,000 r/	9,190,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 9, 1997.

3/ In addition to the countries listed, Canada and China are believed to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of ouput levels.

4/ Includes bentonitic clays.

5/ Reported figure.

6/ Year beginning Mar. 21 of that stated.

7/ May include other clays.

8/ Dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries, except Armenia and Turkmenistan.

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TABLE 26
FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria	3,656	3,229	4,550	4,500 e/	4,500
Argentina e/	1,500	1,600	1,600	1,600	1,500
Australia (attapulgite) e/	15,000	15,000	15,000	15,000	15,000
Germany (unprocessed)	673,000	670,000 e/	498,000	600,000 r/ e/	600,000
Italy e/	28,000 4/	30,000	30,000	30,000	30,000
Mexico	41,111	36,068	21,377	15,755 r/	15,800
Morocco (smectite)	38,098	38,680	22,782	15,027 r/	16,623 4/
Pakistan	22,042	20,941	15,335	12,862	13,415 4/
Senegal (attapulgite) e/	112,336 4/	119,000	119,000	120,000	120,000
South Africa (attapulgite)	8,235	7,030	10,230	8,049	14,318 4/
Spain (attapulgite)	94,546 r/	98,336 r/	91,124 r/	93,829 r/	90,000
United Kingdom 5/	189,400	187,100	134,000	132,300 r/	135,000
United States 6/	2,410,000	2,450,000	2,640,000	2,640,000	2,600,000 4/
Total	3,640,000 r/	3,680,000 r/	3,600,000 r/	3,690,000 r/	3,660,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Excludes centrally planned economy countries and former such countries, some of which presumably produce fuller's earth, but for which no information is available. Table includes data available through July 9, 1997.

3/ In addition to the market economy countries listed, France, India, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Salable product.

6/ Sold or used by producers.

TABLE 27
KAOLIN: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria	20,844	12,586	16,984	24,068	24,000
Argentina	43,722	42,052	50,471 r/	40,000 r/	40,000
Australia (includes ball clay) e/	180,000	180,000	200,000	210,000	210,000
Austria (marketable)	64,733	64,381	65,000 r/	57,000 r/	60,000
Bangladesh 4/	7,300 e/	7,500	3,283 r/	6,541 r/	7,000
Belgium e/	325,000	300,000	300,000	300,000	300,000
Bosnia and Herzegovina e/	3,000	3,000	3,000	3,000	3,000
Brazil (beneficiated)	810,976 r/	900,000 r/	953,000 r/	1,070,301 r/	1,000,000
Bulgaria	104,000	111,000	115,000	115,000 e/	115,000
Burundi e/	9,688 5/	5,000	5,000	1,000	1,000
Chile	59,083	66,939	73,081	70,000 e/	70,000
Colombia (includes common clay)	2,050,000 e/	2,097,491	6,700,000	7,300,000	7,500,000
Czech Republic 6/	XX	2,336,000	2,522,000 r/	2,890,000 r/	3,320,000 5/
Czechoslovakia (marketable) 7/	700,000 e/	XX	XX	XX	XX
Denmark (sales) e/	3,503 5/	3,500	3,500	3,500	3,000
Ecuador	6,380	12,000	6,883	8,000 r/	7,000
Egypt	203,473	184,004	180,000 e/	180,000 e/	180,000
Eritrea	XX	XX	5,231	3,185 r/	2,620 5/
Ethiopia e/ 8/	420	500	--	--	--
France (marketable)	334,000	295,000 e/	327,000	345,000 r/	350,000
Germany e/	1,190,000	981,000	1,631,000 5/	600,000 r/	600,000
Greece	201,705	200,000 e/	117,254	125,000 e/	125,000
Guatemala e/	2,860 5/	3,000	3,000	3,100	3,100
Hungary (processed)	7,000	15,000	5,000 r/	4,847 r/	5,000
India:					
Processed	124,000	129,271	134,000	160,000 r/	160,000
Saleable crude	514,000	518,629	548,000	552,000 r/	550,000
Indonesia	230,550	42,365	53,236	14,373 r/	15,000
Iran	264,083	254,413	250,000 e/	250,000 e/	250,000
Israel e/	53,000	40,000 5/	40,000	40,000	40,000

See footnotes at end of table.

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TABLE 27--Continued
KAOLIN: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Italy:					
Crude	33,017	--	--	--	--
Kaolinitic earth e/	15,000	15,000	7,000 r/	10,000	10,000
Japan	122,948	110,318	138,412	182,122 r/	141,230 5/
Korea, Republic of	1,856,157	2,328,921	2,675,485	2,792,139 r/	2,800,000
Madagascar e/	756 5/	1,000 r/	1,200 r/	1,545 r/ 5/	1,500
Malaysia	244,573	249,852	252,628	211,182	209,562 5/
Mexico	144,121	216,000	193,034	221,685 r/	251,302 5/
New Zealand	27,520	26,543	40,720 r/	13,662 r/	15,000
Nigeria e/	1,300	1,300	105,000	100,000	100,000
Pakistan	37,444	37,179 r/	47,894	30,746	54,860 5/
Paraguay e/	74,000	74,000	74,000	66,300 r/ 5/	74,000
Peru	5,500	5,100 r/	5,100 r/	8,445 r/	14,295 5/
Poland	42,400	47,900 r/	52,000 r/	53,000 r/	55,000
Portugal e/	194,190 r/ 5/	178,000 r/	180,000 r/	150,000 r/	150,000
Romania	50,000 r/ e/	50,000 r/ e/	47,566 r/	49,024 r/	45,200 5/
Serbia and Montenegro:					
Crude	111,782	37,627	69,927 r/	56,926 r/	55,000
Washed	9,300	4,800	7,110 r/	4,900 r/	5,000
Slovakia 6/	--	25,000	24,100 r/	13,300 r/	23,240 5/
Slovenia: e/					
Crude	15,000	10,000	10,000	10,000	10,000
Washed	5,000	4,000	4,000	4,000	7,000
South Africa	131,765	147,349	131,863	146,587	146,496 5/
Spain (marketable): 9/ Crude and washed	379,591	284,382 r/	337,339 r/	399,248 r/	400,000
Sri Lanka e/	6,759 5/	7,000	7,500	7,500	7,500
Sweden e/	100	100	100	100	100
Taiwan e/	100,000	100,000	100,000	100,000	100,000
Tanzania e/	1,360	-- r/	-- r/	-- r/	--
Thailand (beneficiated)	301,035	397,330	417,064	460,629	450,000
Turkey	134,416	210,356	179,775	489,635 r/	400,000
Ukraine	1,200,000 e/	1,100,000 e/	1,015,000	950,000	900,000
United Kingdom (sales) 10/	2,502,224	2,577,160	2,653,918 r/	2,585,881 r/	2,650,000
United States 11/	8,740,000	8,830,000	8,770,000	9,480,000	9,120,000 5/
Uzbekistan e/	7,000,000	5,500,000	5,500,000 r/	5,500,000 r/	5,500,000
Venezuela	37,000	22,000	10,345	3,020	9,000 p/
Vietnam e/	800	800	1,000	1,000	1,000
Zimbabwe	83	90 e/	462	57 r/	50
Total	31,000,000	31,400,000 r/	37,400,000 r/	38,500,000 r/	38,600,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 9, 1997.

3/ In addition to the countries listed, China, Morocco, and Suriname may also have produced kaolin, but information is inadequate to make reliable estimates of output levels.

4/ Data for year ending June 30 of that stated.

5/ Reported figure.

6/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

7/ Dissolved Dec. 31, 1992.

8/ Data for year ending July 7 of that stated.

9/ Includes crude and washed kaolin and refractory clays not further described.

10/ Dry weight.

11/ Kaolin sold or used by producers.

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COAL COMBUSTION BYPRODUCTS

By Rustu S. Kalyoncu

Electricity accounts for about 35 % of the primary energy use in the United States and is produced by electric power generators designed to convert different fuel types into electricity. Electric power utilities are the largest coal consumers in the United States, as more than one-half the electricity in the United States is generated by burning coal, which translates into almost 90% of coal consumed. As a result, more than 100 million tons of solid residues known as coal combustion products (CCPs) are produced by electric utilities annually. This figure promises to rise considerably, owing mostly to the anticipated rise in the use of flue gas desulfurization (FGD) units in the control of Sulfur dioxide (SO_2) emissions.

The majority of electric power utilities, especially in the Eastern and Midwestern states, use high sulfur bituminous coal. Increased use of high-sulfur coal has contributed to an acid rain problem in North America. To effectively address this problem, the U.S. Congress passed the Clean Air Act Amendments of 1990 (CAAA'90-Public Law 101-549) with stringent restriction on sulfur oxides emissions.

CCPs are the resultant solid residues produced upon coal burning in the production of electricity. The coal is crushed, pulverized, and blown into a combustion chamber, where it immediately ignites to heat the boiler tubes. Upon burning of the coal, the inorganic impurities, known as coal ash, either remain in the combustion chamber or are carried away via the flue gas stream. Coarse ash particles (bottom ash and boiler slags) fall to the bottom of the combustion chamber, while the fine portion (fly ash) remains suspended in the flue gas. Before leaving the stack, these fly ash particles are removed from the flue gas by electrostatic precipitators or other available scrubbing systems, such as mechanical dust collectors, often called cyclones or multicones. Added to the ash is the FGD material as the flue gas is "scrubbed" to remove the sulfur oxides. Among the nonfuel mineral sources, CCPs rank just behind crushed stone and sand and gravel in total tonnage in the United States, surpassing portland cement and iron ore.

The SO_2 reduction provision of CAAA'90, with its two phase implementation plan, has forced the electric utilities to find ways of reducing SO_2 emissions. Many utilities have switched to low-sulfur coal or fuel oil as partial and temporary solution to the problem. A significant number of powerplants still using medium- or high-sulfur coal installed flue gas desulfurization equipment from among a number of commercially available units. Wet lime FGD systems, later described, most commonly used in the United States, yield a byproduct known as FGD material.

FGD units solve the SO_2 problem, but add another in the form of large quantities of byproduct FGD material. Produced in inordinate quantities, FGD material adds to the accumulation of already high levels of CCPs. Of approximately 20 million metric tons of FGD material, produced in 1993, less than 5% was utilized as a substitute for natural gypsum, mostly in agriculture and wallboard manufacturing. Synthetic gypsum use represented less than 4% of total gypsum consumed and approximately 5% of crude gypsum produced from 61 mines in the United States.

Among the industries directly or indirectly affected by the FGD gypsum issues are coal, limestone, lime, soda ash, and gypsum producers. Increased commercial use of FGD products represents an economic opportunity for the sorbent industry and the high-sulfur coal producers.

In addition to the FGD material, CCPs include fly ash, bottom ash, and boiler slag. Cumulative quantities of CCP's produced since 1987 are more than 700 million metric tons. Boiler slags represent a minor component of CCPs. One hundred percent of boiler slags is profitably utilized, mostly in the manufacture of abrasives and roofing granules. Among the major CCP components, bottom ash has over the years represented the highest use rate at approximately 35% of the amount produced.

FGD Technology

Numerous processes and equipment to reduce SO_2 and Nitrogen oxides (NO_x) emissions have been developed, and many are commercially available. A significant number of electric powerplants, which continue to use medium- and high-sulfur coal as fuel, have installed FGD equipment. Close to 200 FGD systems, with small to significant variations have been described in the literature (Radian Corp., 1983). These systems are divided into two major types, wet and dry systems, which, in turn have been assigned to 16 categories, wet systems (calcium, sodium, ammonia, magnesium, potassium, organic, and others) and dry systems (reagent, carbon sorption, combustion, metal oxide sorption, catalytic oxidation, SO_2 reduction, etc.). Among the numerous systems mentioned, only a few have been developed to technically and economically feasible levels, and even fewer to commercial scale. Among these, the lime-limestone process is the most widely used system in the United States.

FGD Methods

Passage of the CAAA'90 by the 101st Congress brought about FGD requirements for coal-fired powerplants. This generated a beehive of activity in the research and development of FGD processes for the control of SO_2 emissions in the flue gas. Close to 200 FGD processes and 24 subsystems of

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processes have been reported. Description of all the processes, even in a summary fashion, is beyond the scope of this publication. A list of categories and the number of processes within the categories are shown in table 1.

The major process division is between wet and dry systems. Wet systems completely saturate the flue gas with moisture while dry systems do not. With wet FGD systems , the fly ash is usually removed from the flue gas stream prior to the flue gas entering the FGD system. A large majority of the processes are systems that have been proposed but never carried beyond the laboratory due to poor performance or unfavorable economics. A summary of the development status of FGD Systems are shown in table 2.

Lime-Limestone-Based Systems

The great majority of FGD systems—about 90%—being installed in the United States utilize limestone or lime as a sorbent. Currently, more than 10,000 megawatts (MW) of electric power generating capacity use FGD systems. An additional 23,000 MW are either in the construction or the planning stages for retrofit with FGD units (Mc Ilvane Co.).

Lime is more reactive than limestone; consequently, higher efficiencies can be obtained with lime as the sorbent, and thus lesser amounts are needed. This, in turn, results in reduced quantities of byproducts. In FGD systems using the quick lime (CaO) process, quicklime is slaked on site to form a calcium hydroxide slurry. This slurry is added to the reaction tank or scrubber basin, where it is mixed with recycled slurry from the scrubber. In the wet systems, the flue gas stream is sprayed with the lime slurry. The lime reacts with sulfur gases to form calcium sulfite and calcium sulfate. Sulfites formed need to be converted to sulfate. This is accomplished by increasing the oxygen content in the system, thus effecting the oxidation of sulfite to sulfate. The oxidation of sulfite to sulfate is dependent upon many process variables such as equipment design, pH, O_2:SO_2 ratio etc., and has caused serious operating problems due to scale formation in some systems.

Briefly, in a typical system, illustrated in figure 1, the flue gas comes in contact with a slurry of lime or limestone, ground to approximately 90% 200 mesh, and the reagent. The gas may or may not contain fly ash, depending on the absorber design. A larger amount of slurry (relative to the gas volume) is sprayed or dispersed in the contactor, saturating the flue gas and removing the SO_2. The scrubbed gas is then passed through mist eliminators and is often reheated to restore buoyancy prior to discharge.

The SO_2 -rich liquor typically drains into large tanks where neutralization and precipitation reactions occur. Alkaline reagents may be added to the system to control the acidity.

Production

Table 3 depicts the history of CCP production data, collected by American Coal Ash Association (ACAA) through survey of its member utility companies, for the years 1992 through 1996. The data show that the expected rise in the production did not take place after the passage of the CAAA '90. Even though only 10% of the utilities were affected by the first-phase implementation of the law, it was still expected to make a noticeable difference in the CCP quantities produced, due to the increase in the FGD sludge production. This did not take place largely owing to the fact that many utilities, to avoid high initial capital expenditures for FGD installations, opted for temporary solutions, such as fuel switching, power reduction, and purchase of emissions allowances. This trend has continued to date. The commencement of the implementation of the second phase of the law, which encompasses the remaining 90% of the utilities affected, will render the first-phase options, especially emissions allowances, insufficient for minimum compliance. Even if such options were still available, they would probably be equal to the cost of retrofitting utilities with FGD technology. The utilities, therefore, will be compelled to find a permanent solution to the emission problems. They likely will find it in the installation of FGD units. It is, therefore, anticipated that in the coming years the number of FGD units will increase, hence a commensurate rise in the FGD material will substantially add to the total of CCPs produced. This, however, remains to be seen.

Consumption

Table 3 illustrates the history of CCP usage between 1992 and 1996. For the year 1996, boiler slags have led the way with a use rate of 92.3%, followed by bottom ash with 30.45% use. The FGD material, though with the smallest use percentage, has recorded the largest increase in use percentages among the CCPs, jumping from 1.8% in 1992 to 7% in 1996, representing a 3.5-fold increase. The comparison of the production and use data shows that while the quantities of CCPs produced have steadily increased from 80.6 million metric tons in 1992 to 92.4 million metric tons in 1996 (a 14.5% increase in 5 years), the quantities of CCPs used during the same period increased at even a faster rate during the same period, going from 18.5 million tons in 1992 to 23 million tons in 1996, which is almost a 25% increase over the past 5 years.

Table 4 summarizes the 1996 production and use data for individual CCP categories method of handling and specific use areas. The cement and concrete industry uses the greatest quantities of CCPs, accounting for approximately one-third of total CCPs used, followed by structural fills (2.7%) and blasting grit and roofing granules (2.1%), which account for all the boiler slags used. Tables 5 and 6 present the 1996 production and use data—illustrated in table 4, for dried and ponded categories, respectively. Comparison of the two tables points to the fact that greater portion of the dried product is more suitable for beneficial uses, as illustrated by the total use percentages for the two categories.

Figures 5 and 6 are graphic representations of the production and use data summarized in table 3. The production and use data for CCPs are summarized on regional basis and various use categories in figures 4 through 8. Figures 4 and 5 depict total CCPs produced and used in 1996. Figure 5 presents

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separate data for six regions of the country. (See figure 13 for the States in each geographic region.) Figure 6 summarizes the production data by geographic region and by the CCP type, whereas figures 7 and 8 show individual share of each CCP produced and used, respectively. As figures 4 and 5 illustrate, in spite of significant gains in recent years, with the exception of boiler slags, almost 100% of which is used, only a small fraction of total CCPs is profitably utilized.

Components of CCPs have different uses as they exhibit distinct chemical and physical properties making each one suitable for a particular application. Current uses of CCPs include in cement, concrete, mine backfill, agriculture, blasting grit and roofing applications.

Other current uses include, to a lesser extent, waste stabilization, road base-subbase, and wallboard production (FGD gypsum). Recently, the use of FGD gypsum in wallboard production has significantly increased. In the past year, three wallboard companies have announced plans to build wallboard plants that will use FGD gypsum as their raw materials. Potential uses also include applications in subsidence control, acid mine drainage control, and as fillers and extenders. Figures 9 through 12 summarize the leading applications for the four CCPs, namely fly ash, bottom ash, FGD product, and boiler slags.

Fly ash is used in the largest quantities accounting for 60% of the total CCPs used. As depicted in figure 9, use in cement and concrete production tops the list of leading fly ash applications with more than 50%, followed by structural fills and waste stabilization. Figure 10 lists the leading bottom ash applications. Approximately one-half of bottom ash was used in road base-subbase, cement and concrete, structural fill, waste stabilization, and snow and ice control. Miscellaneous other applications, such as mineral fillers and extenders, flowable fill, etc., make up the other half of the use categories. Mining applications (about one-half of the total used), agriculture (about one-third), and blasting/roofing granules account for the bulk of FGD product uses, amounting to more than 90% of its total use, as illustrated in figure 11. Boiler slag uses are summarized in figure 12. Virtually 100% of the boiler slags produced are utilized. Owing to its considerable abrasivity, boiler slag is used almost exclusively in the manufacture of blasting grit and roofing granules.

Current Research and Technology

Research and development (R& D) activities have been in two distinct directions, namely developing FGD methods and finding new application areas for the CCPs, especially the FGD product. Owing to the proprietary nature of FGD technology developments, open literature is void of any significant information on the subject. Promotional efforts at various technical conferences by a number of manufacturers, however, indicate a beehive of activity in the new FGD technologies area, spearheaded by Japanese and European researchers. Higher R & D activity levels in these countries is no surprise as, due to the space requirements, the utility industries in these countries have no room for the disposal of the coproducts from the current FGD processes that produce large quantities of process byproducts. They are, therefore, forced to find better solutions to flue gas emission problems. Research efforts emphasize the development of technology that require less space for installation and yield smaller quantities of coproducts than the current well-established methods using lime or limestone as sorbents.

R&D efforts in FGD technologies have largely been directed toward either decreasing the quantities of the reaction coproducts or increasing their economic value to upgrade them as resource rather than waste products. The ultimate goal, of course, would be to eliminate altogether any coproducts in FGD processes.

Outlook

CCP's will be proportional to the increase in coal use for electric power production. This may be limited to 5% to 7% per year. Increases in the FGD product, however, is another matter. As afore-mentioned phase one of the CAAA'90 affected only 10% of the coal burning electric utilities. With phase two, the remaining 90% of the utilities will be subject to the emissions restrictions set by the law. The majority of the utilities affected by phase one got by restrictions on short-term remedies, such as fuel switching, emission allowance purchases, and reduction of power production where feasible. Such temporary measures, however, shall not be available to all. Simple arithmetic dictates that annual (1996) FGD production may increase an order of magnitude to almost 200 million tons, exceeding the total quantities of the other CCPs. A sufficient number of wet lime based FGD units are already under construction to triple the amount of FGD material produced. The planned capacity may bring it up to fivefold to sixfold of the current amounts. This will present a challenge to several industries, such as construction, agriculture, and certain manufacturing sectors, to find additional uses for these materials.

References Cited

Radian Corporation, The Evaluation and Status of Flue Gas Desulfurization Systems, Research Project 982-28, Final Report January 1984.

McIlvane Company, FGD and DeNOx Manual, V. 2.

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TABLE 1
FGD PROCESS CATEGORIES

Categories	Number of processes
Calcium-Base Wet Systems	24
Sodium-Base Wet Systems	24
Ammonia-Base Wet Systems	12
Magnesium-Base Wet Systems	9
Potassium-Base Wet Systems	5
Organic-Based Wet Systems	22
Other Wet Systems	34
Wet Reagent Dry Systems	5
Dry Reagent Dry Systems	4
Carbon-Based Sorption Systems	10
Metal Oxide Sorption Systems	9
Other Solid Sorption Systems	5
Catalytic Oxidation Systems	11
SO2 Reduction Systems	8
Combustion Systems	2
Other Dry Systems	5
FGD Subsystems	24

Source: Radian Corporation.

TABLE 2
STATUS OF FGD SYSTEMS

Status	Number of processes
Commercial - 100 MW or greater FGD capacity use	10
Commercially available - domestic or foreign	14
Commercially used in other industries	10
Prototype - integrated process operation at utility site	19
Experimental - laboratory and pilot scale	74
Conceptual - not tested beyond fundamental chemistry	37
Unknown - insufficient information	26

Source: Radian Corporation.

TABLE 3
HISTORICAL COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

(Thousand metric tons, unless otherwise specified)

	1992	1993	1994	1995	1996
Fly ash:					
Production	43,600	43,400	49,800	49,200	53,900
Use	11,900	9,540	11,700	12,300	14,800
Percent use	27.30	22.00	23.60	25.00	27.50
Bottom ash:					
Production	12,600	12,900	13,500	13,800	14,600
Use	3,510	3,840	4,610	4,600	4,430
Percent use	27.80	29.80	34.30	33.30	30.40
Boiler slag:					
Production	3,730	5,660	3,440	2,550	2,360
Use	2,810	3,110	2,830	2,440	2,180
Percent use	75.20	55.10	82.30	95.70	92.30
FGD material:					
Production	14,400	18,500	14,100	18,100	21,700
Use	260	1,050	850	1,340	1,510
Percent use	1.83	5.70	6.05	7.41	6.96
Total CCP:					
Production	74,400	80,400	80,800	83,700	92,400
Use	18,500	17,500	20,000	20,700	23,000
Percent use	24.80	21.80	24.80	24.90	24.90

Source: American Coal Ash Association (ACAA).

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TABLE 4
TOTAL 1/ COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

(Thousand metric tons, unless otherwise specified)

	Fly ash	Bottom ash	Boiler slag	FGD material	Total all CCPs
Production:					
Disposed	37,100	9,210	220	15,800	62,300
Produced	53,900	14,600	2,360	21,700	92,400
Removed from disposal	1,200	150	130	70	1,550
Stored on-site	3,290	1,100	70	4,440	8,890
Use:					
Agriculture	10	10	--	--	20
Blasting grit/roofing granules	--	150	1,970	--	2,130
Cement/concrete/grout	7,280	690	--	60	8,040
Flowable fill	280	40	--	10	330
Mineral filler	150	30	50	--	220
Mining applications	690	60	--	30	770
Roadbase/subbase	680	660	--	110	1,440
Snow and ice control	--	610	100	--	710
Structural fills	1,970	610	40	50	2,670
Wallboard	10	--	--	790	810
Waste stabilization/solidification	1,750	230	--	50	2,040
Other	1,910	1,340	10	400	3,660
Total use	14,700	4,430	2,170	1,500	22,800
Individual use percentage	27.50	30.40	92.30	6.96	NA
Cumulative use percentage	27.40	28.00	30.10	24.90	24.90

NA Not available.

1/ Total CCPs include Categories I and II; Dry and Ponded respectively.

Source: American Coal Ash Association (ACAA).

TABLE 5
DRY COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

(Thousand metric tons, unless otherwise specified)

	Fly ash	Bottom ash	Boiler slag	FGD material	Total all CCPs
Production:					
Disposed	25,400	5,500	150	9,370	40,400
Produced	39,000	8,610	880	11,100	59,600
Removed from disposal	170	30	10	0	210
Stored on-site	2,020	360	10	410	2,810
Use:					
Agriculture	10	10	--	--	20
Blasting grit/roofing granules	--	10	650	--	660
Cement/concrete/grout	6,960	490	--	60	7,510
Flowable fill	250	40	--	10	300
Mineral filler	150	10	10	--	170
Mining applications	420	40	--	--	460
Roadbase/subbase	670	480	--	110	1,250
Snow and ice control	--	360	20	--	380
Structural fills	1,140	240	40	50	1,470
Wallboard	10	--	--	740	750
Waste stabilization/solidification	1,010	230	--	50	1,300
Other	1,110	890	--	320	2,320
Total use	11,700	2,800	720	1,340	16,600
Individual use percentage	30.10	32.40	82.60	12.10	NA
Cumulative use percentage	30.10	30.50	31.50	27.80	27.80

NA Not available.

Source: American Coal Ash Association (ACAA).

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TABLE 6
PONDED COAL COMBUSTION PRODUCT (CCP) PRODUCTION AND USE

(Thousand metric tons, unless otherwise specified)

	Fly ash	Bottom ash	Boiler slag	FGD material	Total all CCPs
Production:					
Disposed	11,700	3,710	70	6,410	21,900
Produced	14,900	5,970	1,450	10,500	32,900
Removed from disposal	1,030	120	120	70	1,340
Stored on-site	1,260	740	50	4,030	6,080
Use:					
Agriculture	--	--	--	--	--
Blasting grit/roofing granules	--	150	1,320	--	1,470
Cement/concrete/grout	330	200	--	--	530
Flowable fill	40	--	--	--	40
Mineral filler	--	20	40	--	60
Mining applications	270	20	--	20	310
Roadbase/subbase	10	180	--	--	190
Snow and ice control	--	240	80	--	320
Structural fills	830	370	--	--	1,200
Wallboard	--	--	--	50	50
Waste stabilization/solidification	740	--	--	--	740
Other	800	450	10	80	1,330
Total use	3,020	1,630	1,450	150	6,240
Individual use percentage	20.20	27.30	99.80	1.50	NA
Cumulative use percentage	20.20	22.20	27.20	19.00	19.00

NA Not available.

Source: American Coal Ash Association (ACAA).

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FIGURE 1 TYPICAL WET LIME/LIMESTONE FGD SYSTEM ARRANGEMENT

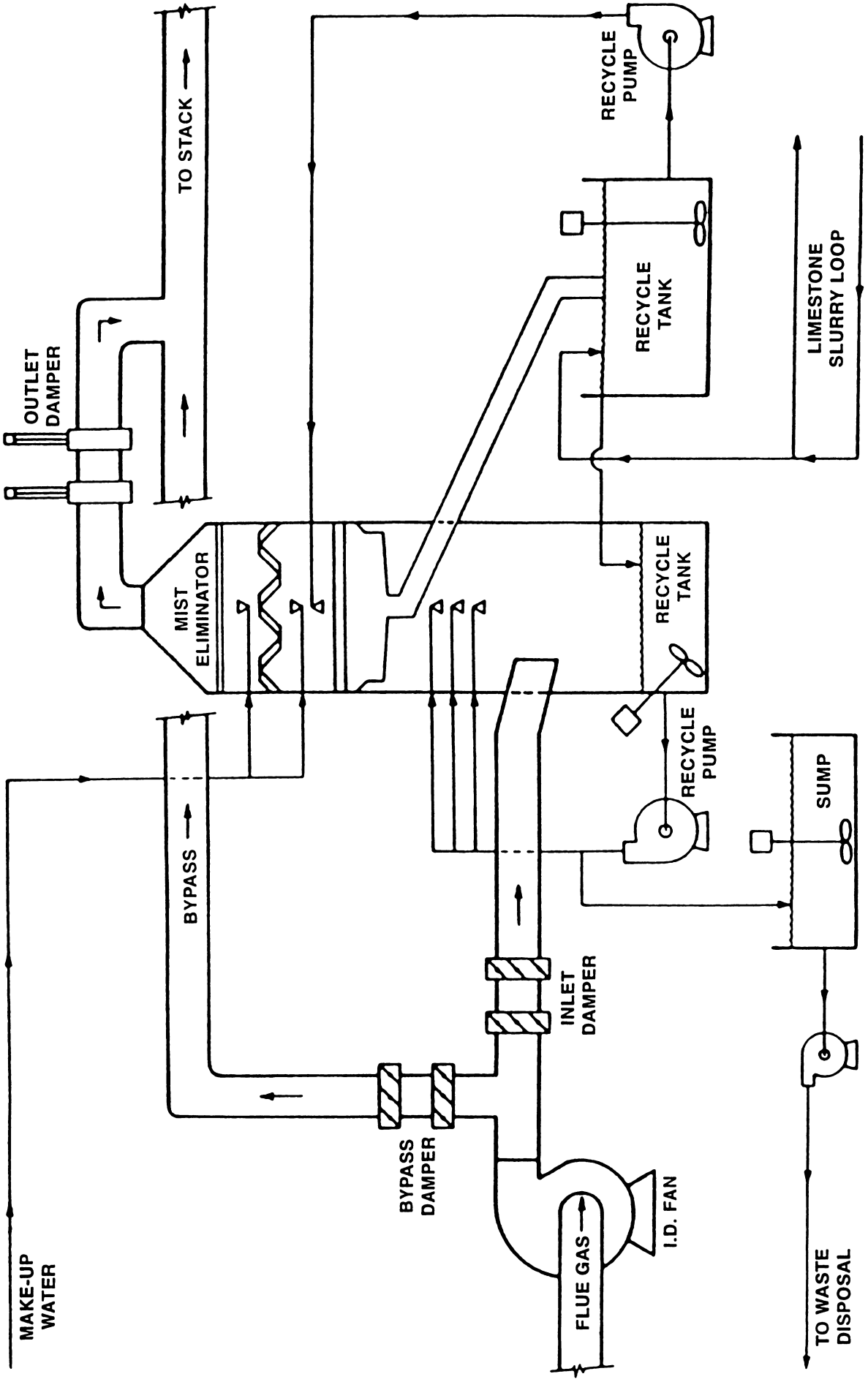

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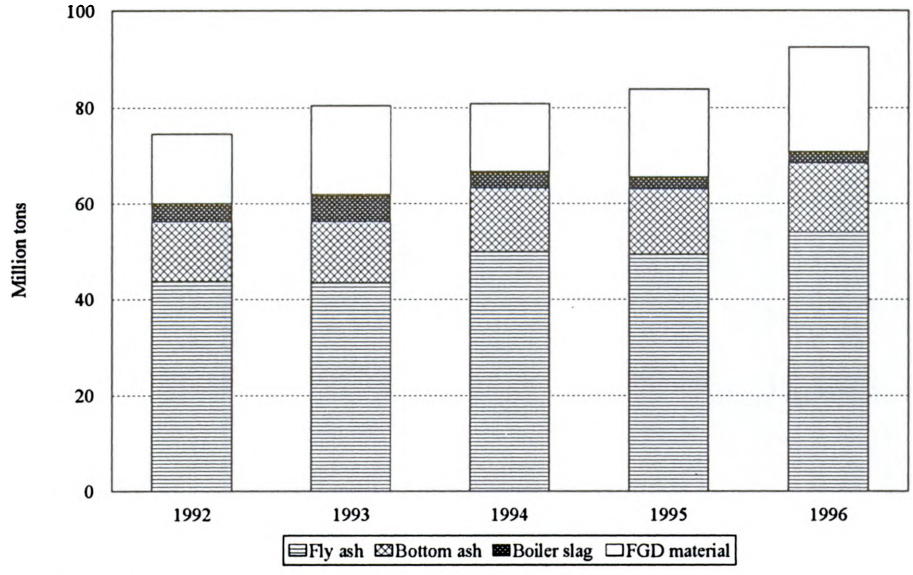
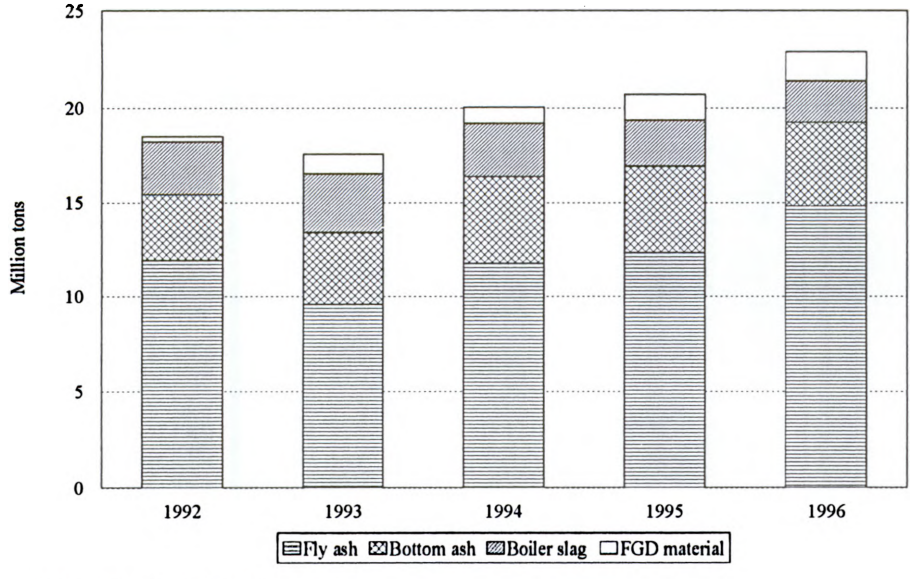
Figure 2. Historical CCP production data, 1992-1996.



Source: American Coal Ash Association.

Figure 3. Historical CCP use data, 1992-1996.



Source: American Coal Ash Association.

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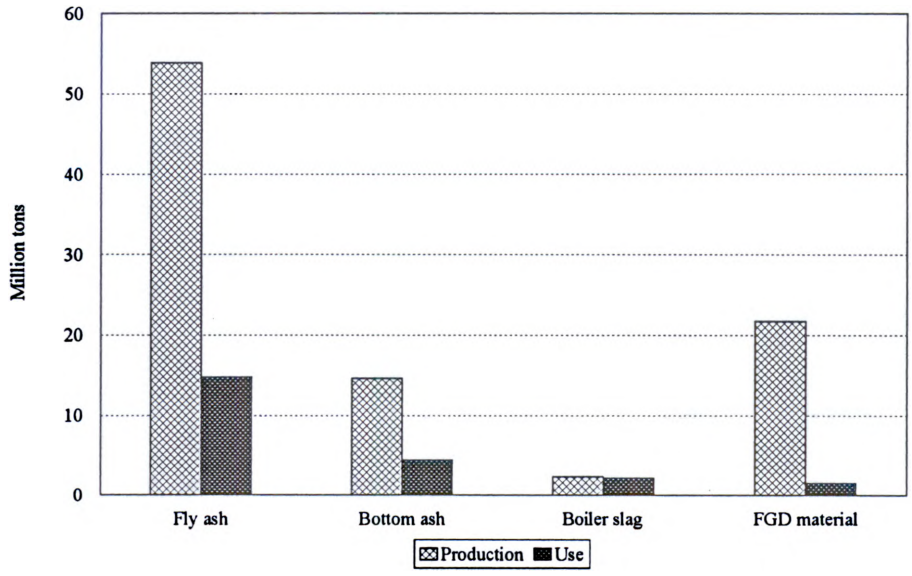
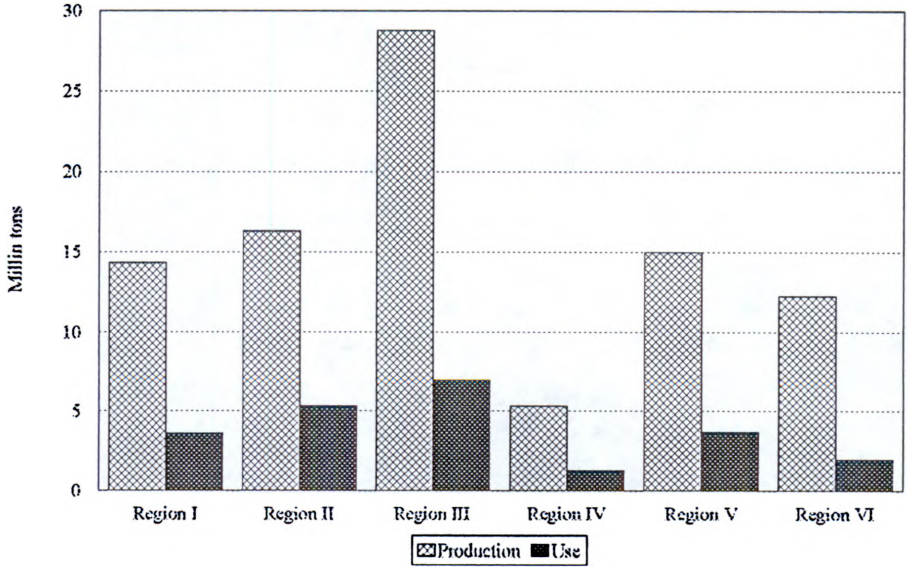
Figure 4. CCP production and use for the United States, 1996.



Source: American Coal Ash Association.

Figure 5. CCP production and use by region.



Source: American Coal Ash Association.

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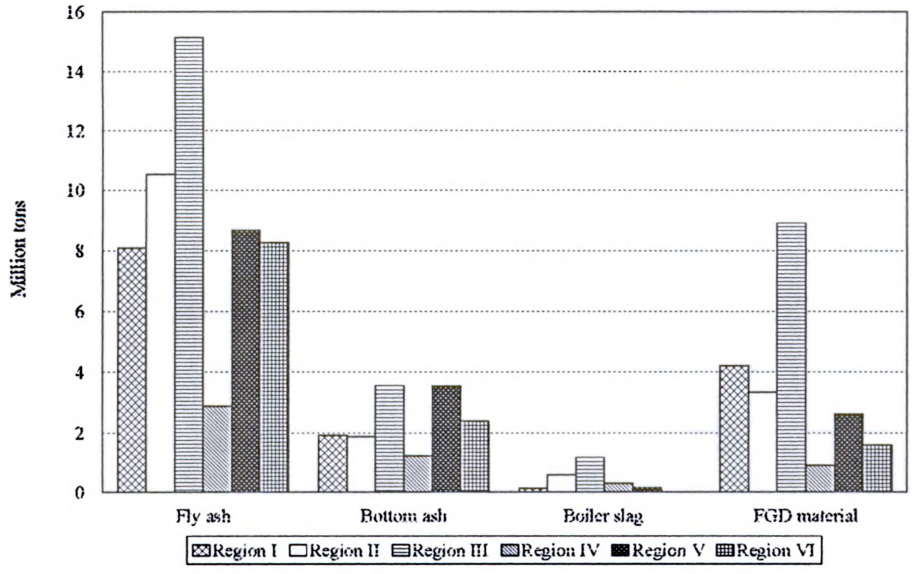
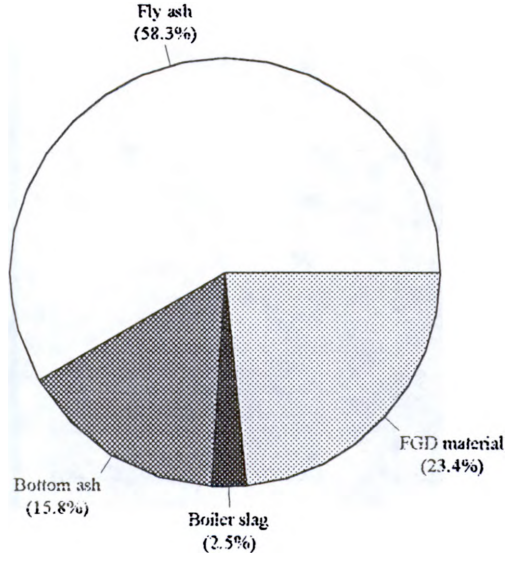
Figure 6. CCP production by type and region.



Source: American Coal Ash Association.

Figure 7. CCP production by type, 1996.



Source: American Coal Ash Association.

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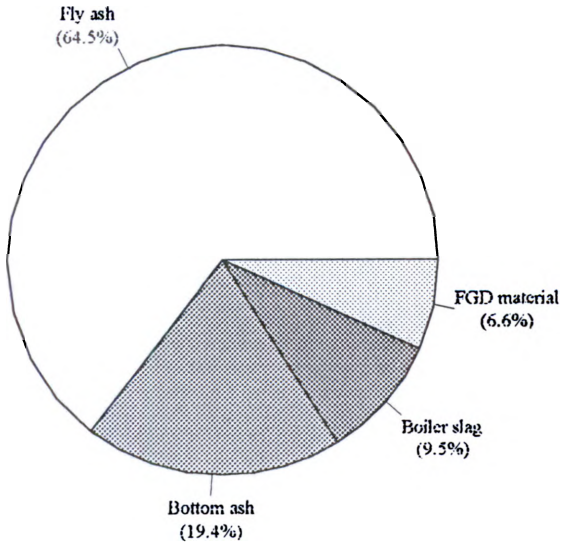
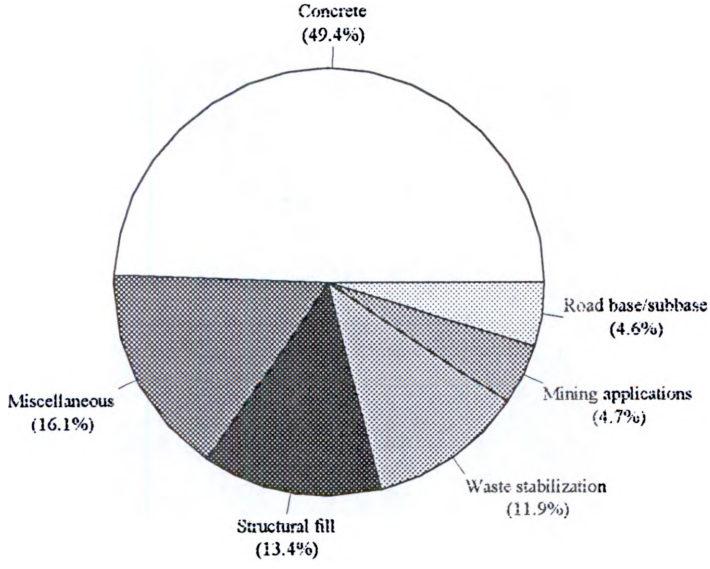
Figure 8. CCP use by type, 1996.



Source: American Coal Ash Association.

Figure 9. Leading coal fly ash uses, 1996.



Source: American Coal Ash Association.

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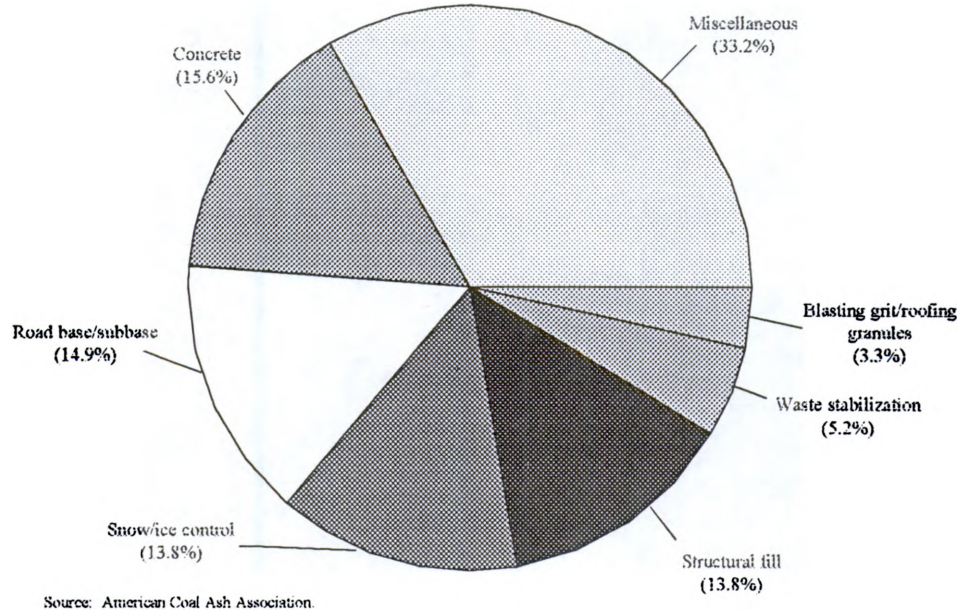
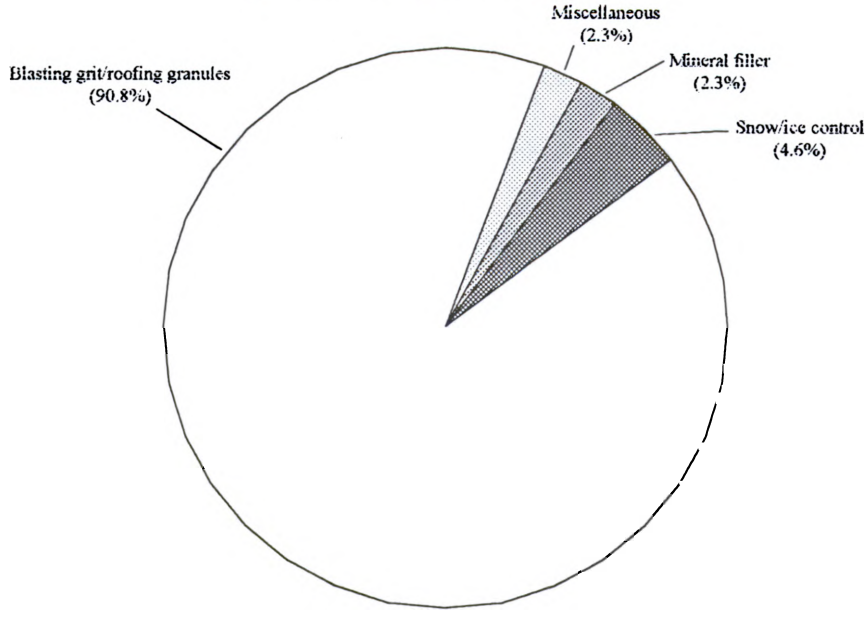
Figure 10. Leading bottom ash uses, 1996.



Source: American Coal Ash Association.

Figure 11. Leading boiler slag uses, 1996.



Source: American Coal Ash Association.

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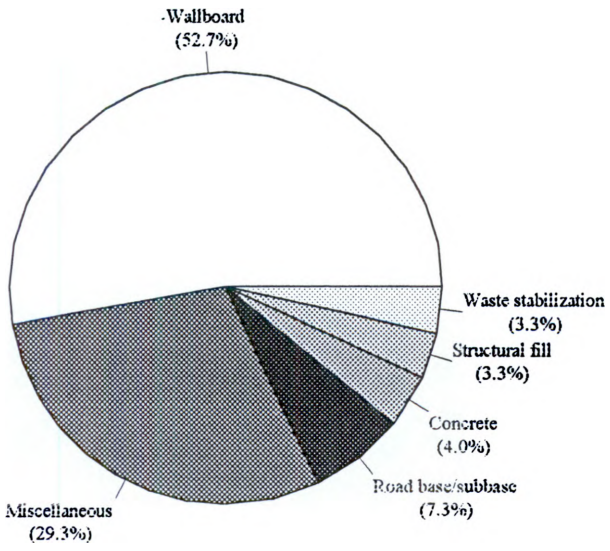
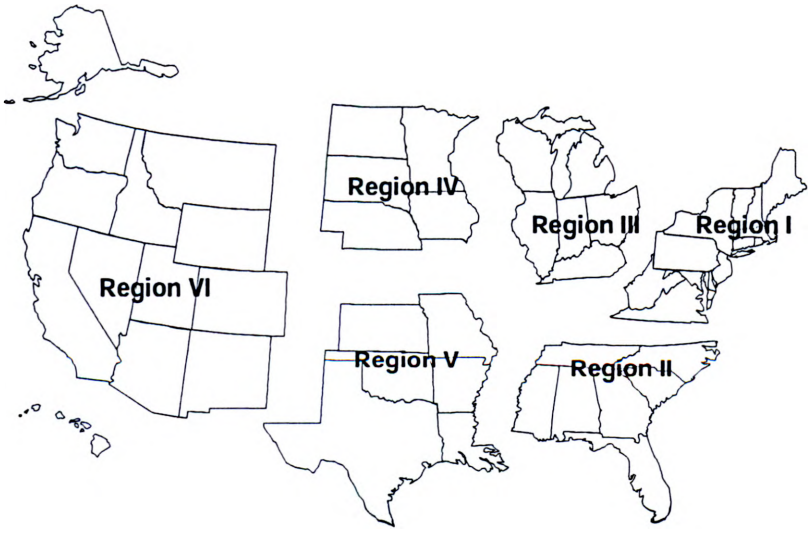
Figure 12. Leading FGD material uses, 1996.



Source: American Coal Ash Association

Figure 13. Regions of the U.S. referred to in figures 5 and 6.



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COBALT

By Kim B. Shedd

Cobalt is a strategic and critical metal used in many diverse industrial and military applications. The largest use of cobalt is in superalloys, which are used to make parts for gas turbine aircraft engines. Cobalt is also used to make magnets; corrosion and wear-resistant alloys; high-speed steels; cemented carbides and diamond tools; catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, and inks; ground coats for porcelain enamels; pigments; battery electrodes; steel-belted radial tires; and magnetic recording media.

The United States is the world's largest consumer of cobalt, but has no mine or refinery production, so it relies on imports to meet its primary cobalt needs. The U.S. Government maintains significant quantities of cobalt metal in the National Defense Stockpile (NDS) for military, industrial, and essential civilian use during a national emergency.

World cobalt production continued to increase in 1996. As in the past few years, cobalt sales from the NDS and exports from Russia contributed to supply. Demand remained strong, but prices decreased during the year.

With the exception of prices and reported production from foreign countries, all data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Legislation and Government Programs

The U.S. Government continued its sales of cobalt from the NDS. During fiscal year 1996 (October 1, 1995, through September 30, 1996), the Defense Logistics Agency (DLA) sold 1,809 tons of cobalt valued at $102 million. This equaled the quantity allowable for sale under the Annual Materials Plan (AMP) for the fiscal year and completed the disposal of the 5,779 tons (12.7 million pounds) of excess cobalt identified in the Department of Defense 1992 Report to the Congress on National Defense Stockpile Requirements.

In September 1996, the 1997 Defense Authorization Bill was signed into law. The bill gave DLA the authority to dispose of an additional 11,793 tons (26 million pounds) of cobalt. The AMP for fiscal year 1997 allowed for a maximum of 2,722 tons (6 million pounds) of cobalt to be sold during the year beginning October 1, 1996. In October, the DLA announced the following sales program: sealed bid sales in December 1996, March 1997, and May 1997; negotiated sales in February 1997, April 1997, and September 1997. Approximately 450 tons (1 million pounds) of 99.0% to 99.59% cobalt would be offered in each sale except the February sale, when 500 tons (1.1 million pounds) of less than 99.0%-pure cobalt would be offered.

The DLA held two cobalt offerings during calendar year 1996. Awards announced in June were made under a negotiated bid basis, while awards made in December were on a sealed bid basis. Between January and December, the DLA sold 1,020 tons of cobalt valued at $151 million. On December 31, the total uncommitted cobalt inventory held by the DLA was 18,176 tons (40.1 million pounds) and the quantity authorized for eventual disposal was 11,793 tons (26 million pounds). *(See tables 1 and 2.)*

Production

There was no domestic mine or refinery production of cobalt in 1996. Formation Capital Corp., of Vancouver, British Columbia, Canada, put its Black Pine copper-cobalt-gold project in Lemhi County, ID, on hold and concentrated on exploring the nearby Sunshine copper-cobalt-gold deposit. Double Creek Mining Corp., also based in Vancouver, acquired a 50% interest in Formation Capital's Salmon Canyon copper property and began an exploration program. The three properties are located in the Idaho Cobalt Belt, which contains Noranda Mining Inc.'s Blackbird Mine, which ceased production in 1959.

U.S. processors made cobalt chemicals and cobalt metal powders from cobalt metal and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production were developed from a monthly voluntary survey of U.S. cobalt processors. Six of the seven companies canvassed for this survey responded. Estimates were made for the nonresponding company. U.S. processors produced 960 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds in 1996, 35% less than the 1,470 tons produced in 1995. Because this figure includes production of intermediate forms, it does not represent net production. Shipments are defined as sales, transfers, or consumption to make end-use products such as paint driers and catalysts. In 1996, shipments by U.S. processors included 1,350 tons of cobalt oxide and hydroxide, inorganic cobalt compounds, and organic cobalt compounds, an 8% decrease from 1995 shipments of 1,460 tons. Two processors made extra-fine cobalt metal powder in the United States. Carolmet, owned by Union Minière S.A. of Belgium, made cobalt metal powder from imported metal at its Laurinburg, NC, plant. Osram Sylvania Inc. made cobalt metal powder from recycled materials in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data.

U.S. cobalt supply included secondary cobalt from alloy scrap, cemented carbide scrap, and spent catalysts. Spent petroleum catalysts were treated by at least four companies in 1996: AMAX Metals Recovery, Inc. in Braithwaite, LA;

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Dakota Catalyst Products Inc. in Williston, ND; Gulf Chemical and Metallurgical Corp. in Freeport, TX; and OMG-Apex in St. George, UT.

Consumption

Apparent consumption (as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks) was basically the same as apparent consumption in 1995. *(See table 1.)* Increases in imports, consumption of scrap, and consumption from stocks were offset by a significant increase in exports.

Reported consumption was developed by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as superalloy producers, magnetic alloy producers, and tungsten carbide producers. For this survey, more than 100 cobalt consumers were canvassed on a monthly or annual basis. The USGS also canvassed 13 superalloy scrap recyclers to determine the consumption of secondary cobalt in superalloy production. Reported consumption and stocks data in tables 1 and 2 contain estimates to account for nonrespondents.

U.S. reported consumption for 1996 was basically the same as reported consumption for 1995. As a whole, metallurgical industries consumed 2% more cobalt in 1996 than in 1995. On an industry-by-industry basis, superalloy melters consumed more cobalt in 1996 than in 1995; producers of welding materials consumed basically the same amount of cobalt during the 2 years; and producers of steel, magnetic alloys, other alloys, cemented carbides, and mill products from metal powder consumed less cobalt in 1996 than in 1995. Total reported cobalt consumption in chemical uses decreased 7% in 1996. Consumption in pigments, decolorizers, and feed materials increased in 1996 as compared with that in 1995, while consumption in catalysts, ground coat frit, and driers decreased. *(See table 2.)*

Prices

Market prices for cobalt decreased in 1996. In January, the U.S. spot cathode price reported by Platt's Metals Week was approximately $32 per pound. By late July the spot cathode price had dropped to a low of $20 per pound. The price increased to approximately $23 per pound in September, but decreased again to $21 to $22 per pound by yearend. Platt's average annual U.S. spot cathode price for 1996 was $25.50 per pound.

Platt's prices for Zambian and Russian cobalt paralleled the U.S. spot cathode prices. In January, the price differential between cathode and Zambian cobalt was minus $2.50 per pound and the price differential between cathode and Russian cobalt was minus $3.75 per pound. As prices decreased the price differentials narrowed. By September, Zambian cobalt was approximately $0.50 per pound less than cathode and Russian cobalt was approximately $0.75 per pound less than cathode.

The reference price set by African producers La Générale des Carrières et des Mines (Gécamines) of Zaire and Zambia Consolidated Copper Mines Ltd. (ZCCM) remained at $27.50 per pound throughout the year.

Foreign Trade

Seven countries supplied 95% of U.S. imports of unwrought cobalt and cobalt in chemicals. Norway was the leading supplier, followed by Finland, Zambia, Canada, Russia, Zaire, and Belgium. Cobalt imports in 1996 were 4% higher than imports in 1995. Imports of cobalt from Finland, Norway, and Zambia increased as compared with those of 1995; imports from Canada, Russia, and Zaire decreased; while imports from Belgium were unchanged from those of 1995. *(See tables 4 and 5.)*

In 1996, the United States imported 60 tons, gross weight, of unwrought cobalt alloys valued at $3.8 million. Seven countries supplied nearly all of these materials: France (24%), Sweden (19%), Belgium (13%), the United Kingdom (12%), Canada and Germany (each 11%), and Japan (10%). The United States imported 566 tons, gross weight, of cobalt matte, waste, and scrap, valued at $11.7 million. Eight countries supplied 92% of these materials: the United Kingdom (21%), Japan (13%), Germany (12%), South Africa (11%), Canada and Finland (each 10%), Brazil (9%), and Russia (7%). The United States also imported 178 tons, gross weight, of wrought cobalt and cobalt articles valued at $11.5 million. The leading suppliers of these materials were Japan (30%), the United Kingdom (41%), France (16%), Germany (6%), and Canada (4%).

U.S. exports of unwrought cobalt and cobalt contained in chemicals increased 28% as compared with exports in 1995. More than three-fourths of 1996 cobalt metal and chemical exports was shipped to six countries: Belgium, Canada, Japan, Mexico, the Netherlands, and the United Kingdom. The remainder was shipped to 42 other countries. *(See table 6.)*

Exports also included 529 tons, gross weight, of wrought metal and cobalt articles valued at $23.5 million. Eighty percent of these materials was sent to seven countries: Hong Kong (19%), the United Kingdom (18%), Canada, Japan, and the Netherlands (each 11%), Taiwan (6%), and France (5%). The remainder was shipped to 29 other countries.

World Review

World cobalt production continued its upward trend in 1996. Refinery production reported by the seven Cobalt Development Institute-member producers increased 31%, from 16,808 tons in 1995 to 22,010 tons in 1996 (Metal Bulletin, 1997).

Australia.—QNI Ltd. made a number of investments to expand production and improve metal recovery rates at its Yabulu nickel-cobalt refinery in Townsville, Queensland. In addition, the company began construction on a plant that would convert Yabulu's cobalt sulfide to cobalt oxide hydroxide. The

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plant was expected to be operational in early 1997. The cobalt oxide hydroxide would be sold as feedstock for the production of cobalt chemicals.

Yabulu's production during the 12-month period ending June 30, 1996, was 1,425 tons of cobalt in cobalt sulfide, basically the same as production during the previous year. Nearly all of the laterite feed for the refinery was from PT Aneka Tambang in Indonesia and four mining companies in New Caledonia. QNI continued its search for additional sources of laterite ore. During the year, QNI signed a contract with Hinatuan Mining Corp. for the supply of trial ore shipments from the Philippines. In July, QNI, Gencor Ltd. of South Africa, and PT Aneka Tambang of Indonesia announced a study to evaluate the possibility of developing integrated nickel-cobalt processing facilities in Indonesia and Australia (QNI Ltd., 1996).

WMC Ltd. (formerly Western Mining Corp. Holdings Ltd.) produced approximately 1,000 tons of cobalt in intermediate products as a byproduct of mining, smelting, and refining nickel sulfide ores in Western Australia. The intermediate products were exported to Outokumpu Oy in Finland, Sumitomo Metal Mining Co. in Japan, and Sherritt International Corp. in Canada to be refined.

Outokumpu Australia Pty. Ltd. produced nickel sulfide concentrates from its Forrestania Mine and concentrator southwest of Kalgoorlie, in Western Australia. The concentrates were exported to Finland for treatment by Outokumpu, where an estimated 100 tons of cobalt was recovered.

Anaconda Nickel NL completed a feasibility study and decided to move forward on its Murrin Murrin nickel-cobalt project. The Murrin Murrin deposit, located between Leonora and Laverton, Western Australia, consists of nickel laterites with a total resource of 117 million tons at 1.10% nickel and 0.08% cobalt. The study indicated that the deposit could be mined by open pit methods over a period of 30 years. Anaconda planned to produce nickel metal powder and cobalt metal powder using the following process: pressure acid leaching, mixed sulfide precipitation and releaching, solvent extraction, then hydrogen reduction. Initial production, forecast to begin in early 1998, would be at an annual rate of 45,000 tons of nickel and 3,000 tons of cobalt. Further expansion to 70,000 tons per year of nickel was being considered. At yearend, Anaconda entered into an agreement with Glencore International AG, whereby Glencore would increase its interest in the Murrin Murrin project to 40% (Anaconda Nickel NL, 1996; Anaconda Nickel Ltd., 1997).

Resolute Samantha Ltd. completed a feasibility study and made a commitment to develop its Bulong nickel-cobalt project. The deposit, located east of Kalgoorlie in Western Australia, is a nickel laterite with a resource of 140 million tons at 1.0% nickel and 0.1% cobalt. Mining would occur in several open pits over a period of 26 years. Ore would be refined by pressure acid leaching, followed by solvent extraction and electrowinning to produce nickel cathode and cobalt cathode. Resolute planned to develop the project in two stages: initial annual production of approximately 9,000 tons of nickel and 600 tons of cobalt, followed by an expansion to 22,000 tons of nickel and 1,800 tons of cobalt. Production was to begin during the first half of 1998 (Resolute Samantha Ltd., 1996; Metal Bulletin, 1996a).

Centaur Mining & Exploration Ltd. completed a feasibility study on its Cawse nickel laterite project north of Kalgoorlie in Western Australia. Exploration during the year upgraded the mineral resource estimate to 193 million tons at 0.7% nickel and 0.04% cobalt. Centaur planned to mine the deposit from a number of shallow pits, screen the ore, then process it with pressure acid leaching. An intermediate nickel-cobalt hydroxide would be produced, then releached in ammonia. Nickel would be recovered by solvent extraction and electrowinning. Cobalt would be produced as a sulfide, which would be sent elsewhere for further processing. Centaur planned to begin production in 1998 at an initial rate of 8,000 tons of nickel and 2,000 tons of cobalt (Centaur Mining & Exploration Ltd., 1996a, 1996b).

Calliope Metals Corp. worked on a feasibility study for a nickel-cobalt refinery to be built in Gladstone, Queensland. Calliope planned to use pressure acid leaching to treat limonitic ore imported from New Caledonia. The proposed refinery would be capable of processing 1.2 million dry tons of ore per year to produce a mixed sulfide containing 18,700 tons of nickel and 1,890 tons of cobalt. Calliope planned to begin production in 1999 (Calliope Metals Corp., 1996; Mattheson, 1996).

Mount Isa Mines Ltd. and Savage Resources Ltd. proceeded with the development of the Ernest Henry copper-gold deposit near Cloncurry, Queensland. The partners planned to begin production in late 1997. A project to recover cobalt from pyrite in Ernest Henry's flotation tailings was under consideration. Bench-scale testing of various oxidation process options began in 1996. Pilot plant scale testing was delayed until mine production begins and bulk concentrate samples become available (Wall, 1996).

The following nickel sulfide projects also have the potential to produce cobalt in the future: Dominion Mining Ltd.'s Yakabindie project, the CRA Ltd./Outokumpu Oy Honeymoon Well project, and the Mining Project Investors Pty. Ltd./Outokumpu Black Swan project. All three of these projects are north of Kalgoorlie in Western Australia. Two copper properties in the Cloncurry area of Queensland also have the potential to produce cobalt: Cloncurry Mining NL's Great Australia copper mine and Majestic Resources NL's White Range copper-cobalt project.

Belgium.—Union Minière S.A. converted cobalt metal, residues, and other cobalt-bearing materials into cobalt metal powders, oxides, hydroxide, and chloride at its facilities in Olen, Belgium.

Brazil.—Cia. Niquel Tocantins produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State. The refinery used lateritic nickel ore from Niquelandia, Goias State, as feed.

RTZ Mineração, a subsidiary of RTZ Corp. Plc. of the United Kingdom, worked on its Fortaleza de Minas nickel sulfide project in Minas Gerais State. The project was to include a mine, concentrator, smelter, and refinery. RTZ planned to begin production in early 1998. Byproduct cobalt would be refined elsewhere (Metal Bulletin, 1996b).

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Canada.—Falconbridge Ltd.'s Sudbury Division produced 1,625 tons of cobalt contained in nickel-copper matte, a 3% increase from 1,574 tons produced in 1995 (Falconbridge Ltd., 1997). Forty-five percent of the cobalt smelted was from nickel-copper ores mined at the company's Sudbury, Ontario, operations. The remaining 55% was from custom feed materials. Matte from Falconbridge's Sudbury smelter was refined at the company's Nikkelverk plant in Norway.

Falconbridge continued with the development of its Raglan nickel-copper property in the Ungava region of northern Quebec. The company planned both open pit and underground mining. Concentrates milled at Raglan would be smelted at Sudbury and the matte produced would be refined in Norway. An estimated 20,800 tons of nickel, 5,200 tons of copper, and 330 tons of cobalt would be recovered annually from Raglan ores (Falconbridge Ltd., 1996). Production was scheduled to begin by late 1997.

Inco Ltd. produced cobalt oxide at its Thompson, Manitoba, refinery and cobalt cathode at its Port Colborne, Ontario, refinery. Feed materials for the two refineries originated from nickel mines in Thompson, Manitoba, and Sudbury, Ontario, respectively. In 1996, Inco produced 1,544 tons of cobalt, a 13% increase over the 1,362 tons produced in 1995 (Metal Bulletin, 1997).

In August, Inco purchased Diamond Fields Resources Inc. and became full owner of the world-class Voisey's Bay nickel-copper-cobalt-sulfide deposit in northeastern Labrador. Exploration at Voisey's Bay continued during the year. By yearend, at least three zones of mineralization had been identified: a near-surface ovoid-shaped body, the Eastern Deeps area, and the Western Extension. Inco reported an "inferred resource" of approximately 150 million tons (Inco Ltd., 1997). Inco hoped that permitting would be completed by May 1998 and initial concentrate production could begin in late 1999 (Inco Ltd., 1996).

In November, Inco selected Argentia, Newfoundland, as the site for the smelter and refinery complex that would process the nickel-cobalt concentrate from Voisey's Bay. Inco planned to have the complex built in time to begin smelting concentrate in the year 2000. At full production Voisey's Bay was expected to yield 122,000 tons of nickel, 90,000 tons of copper, and 3,000 tons of cobalt per year (Inco Ltd., 1997).

In November 1995, Sherritt Inc.'s 50% share in the Metals Enterprise joint venture with General Nickel Co. S.A. of Cuba was transferred to Sherritt International Corp. The Metals Enterprise included The Cobalt Refinery Co. Inc.'s nickel-cobalt refinery at Fort Saskatchewan, Alberta. In 1996, capacity at this refinery was increased to 27,200 tons of nickel and 2,270 tons of cobalt. Cobalt production was a record 2,074 tons, 20% higher than the 1,730 tons produced in 1995 (Sherritt International Corp., 1997). Most of the feed for the refinery was in the form of nickel-cobalt mixed sulfides from Metals Enterprise subsidiary Moa Nickel S.A. of Moa Bay, Cuba. As a result of a U.S. embargo on imports of products originating from Cuba, nickel and cobalt produced at The Cobalt Refinery Co. cannot be sold to U.S. customers.

Ego Resources Ltd. produced cobalt carbonate at its Cobatec refinery near the historic silver mining town of Cobalt, Ontario. The refinery used a hydrometallurgical process to treat ores from local mines and "copper cake" from electrolytic zinc production. During the year Ego reviewed its plant process and decided to discontinue processing ore in favor of cobalt-bearing residues. As a result of this decision, production from two local mines ceased and arrangements were made with outside sources for feedstock (Ego Resources Ltd., 1997).

Canmine Resources Corp. explored cobalt and nickel deposits in the Werner Lake Belt of southwestern Ontario-southeastern Manitoba. In May, Canmine announced that it was to acquire full titles to the Juan cobalt-copper-gold property in Ontario and the Maskwa-Dumbarton nickel-copper-platinum-group-metal property in Manitoba. Canmine planned to develop high-grade cobalt deposits at the Juan property and process the ore at a milling facility to be established at Maskwa. Approximately 300 tons of cobalt in concentrate would be produced from test milling during the first year. Full-scale annual production in later years was targeted at 900 tons of cobalt in concentrate. The mine was being developed on a 50% joint-venture basis with Red Engine Resources Corp. (Canmine Resources Corp., 1996).

China.—Cobalt was produced from both domestic and imported raw materials. At Jinchuan, Gansu Province, cobalt metal was produced as a byproduct of nickel from the refining of domestic nickel sulfide ores. The Ganzhou cobalt refinery in Jiangxi Province produced cobalt metal and salts from cobalt arsenide concentrates imported from Morocco. Minor production sites included the Zibo Cobalt Works in Shandong Province, where cobalt metal was produced from iron ore from Shandong Province and copper ore from Shanxi Province.

Côte d'Ivoire.—Falconbridge, Trillion Resources Ltd., and Société de Développement Minière de la Côte d'Ivoire continued exploration work on nickel laterite deposits in western Côte d'Ivoire. In December, Falconbridge signed a memorandum of understanding with the Government of Côte d'Ivoire that outlined a schedule for the Touba-Biankouma nickel laterite project. The schedule included completion of a study on hydrometallurgical ore treatment during the first quarter of 1997. Exploration identified a total resource of 226 million tons, grading 1.50% nickel and 0.10% cobalt (Falconbridge Ltd., 1997).

Cuba.—Moa Nickel S.A. mined nickel-cobalt laterites at Moa Bay and produced mixed sulfides containing 26,034 tons of nickel and cobalt. This 26% increase over 1995 production was attributed to improved management practices and the overhaul of two sulfuric acid plants at Moa. The mixed sulfides produced at Moa were refined by The Cobalt Refinery Co. in Fort Saskatchewan, Alberta, Canada (Sherritt International Corp., 1997.)

WMC continued negotiations with state-owned Commercial Caribbean Nickel S.A. to finalize detailed plans for a joint-venture project to evaluate and possibly develop the Pinares de Mayari West nickel laterite deposit in Holguín Province.

Nickel and cobalt of Cuban origin cannot be imported into

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the United States because of a U.S. embargo on imports from Cuba.

Finland.—OM Group, Inc. produced a record 4,160 tons of cobalt in cobalt metal powders, oxides, and salts, 15% more than the 3,610 tons produced in 1995 (Metal Bulletin, 1997). In recent years, OM Group's Kokkola Chemicals Oy refinery has used cobalt sulfide from QNI in Australia, cobalt slag and cobalt-nickel hydrate from Gécamines in Zaire, and cobalt hydroxide sludge from Outokumpu's Harjavalta, Finland, refinery as its raw materials feed.

Outokumpu Metals and Resources Oy produced an estimated 500 tons of cobalt metal powder at its newly expanded and upgraded Harjavalta nickel refinery (Karpel, 1996). The cobalt was a byproduct of nickel produced from concentrates imported from the Nikkel og Olivin Mine in Norway and the Mount Keith and Forrestania Mines in Western Australia.

Japan.—Sumitomo produced electrolytic cobalt, cobalt oxide, and cobalt salts as a byproduct of nickel production at its Niihama Nickel Refinery in Ehime Prefecture. Sumitomo's cobalt metal production in 1996 was basically the same as that in 1995.

Mexico.—International Curator Resources Ltd. of Vancouver, British Columbia, continued its investigation of the Boleo copper-cobalt deposit near Santa Rosalia, Baja California. Exploration by the company expanded the "geological resource" to 395 million tons grading 0.88% copper and 0.075% cobalt at a 1% copper-equivalent cutoff grade (International Curator Resources Ltd., 1996). International Curator investigated a leaching-precipitation-flotation process to produce copper and cobalt concentrates, which would then be redissolved and electrowon to produce cathode copper and cobalt. Annual production was forecast at 55,000 tons of copper and 4,500 tons of cobalt beginning in late 1999 (McInnis, 1996).

Morocco.—Cie. de Tifnout-Tiranimine (CTT) began production of cobalt metal in mid-1996. Cobalt tailings from past mining operations at Bou-Azzer were leached in sulfuric acid, purified with solvent extraction, then electrowon to produce 99.9% cobalt cathode. Preliminary treatment of the tailings occurred at a newly constructed plant at the Bou-Azzer Mine. Final purification and cathode production occurred at a newly constructed plant at the Guemassa Mine. CTT planned to produce 220 tons of cobalt cathode per year. This production was to be in addition to the 300 to 400 tons of cobalt in concentrates that CTT exports to China for refining (M'Hamdi, 1996).

New Caledonia.—Lateritic nickel ore from J.C. Berton Mines, Nickel Mining Corp., Société Minière du Sud Pacifique, and Société des Mines de la Tontouta was exported to QNI's Yabulu nickel-cobalt refinery in Queensland, Australia, for processing. Nickel matte from Société Métallurgique Le Nickel's Doniambo smelter was sent to the Eramet Group's refinery in Sandouville-LeHavre, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride. Inco continued work on a feasibility study of its 85%-owned Goro nickel-cobalt property in southern New Caledonia.

Norway.—Falconbridge expanded the cobalt capacity of its Nikkelverk refinery to 3,700 tons per year. The expansion was to accommodate feed from the company's Raglan Mine in Quebec, Canada, and additional custom feed. The company produced 3,098 tons of cobalt cathode at Nikkelverk in 1996, a 10% increase over the 2,804 tons produced in 1995 (Falconbridge Ltd., 1997). Feedstock for the refinery was in the form of matte from company operations in Sudbury, Canada, BCL Ltd. in Botswana, and elsewhere.

Papua New Guinea.—Joint-venture partners Highlands Gold Ltd. and Nord Pacific Ltd. completed a prefeasibility study on their Ramu River laterite project. The study investigated the feasibility of open pit mining, then processing the ore with pressure acid leaching technology. A production rate of 33,000 tons of nickel and 2,800 tons of cobalt over a period of 20 years or more was considered, with initial production beginning in the first quarter of 2001. The partners planned to advance the project toward full feasibility and production (Nord Pacific Ltd., 1996).

Philippines.—At the end of 1995 a consortium of international investors named Pacific Nickel Holdings Ltd. reached an agreement with the Philippine Government to acquire Philnico Mining and Industrial Corp. and rehabilitate the Nonoc nickel mine and refinery complex. The complex, located in Surigao del Norte, Nonoc Island, was closed in 1986 following financial difficulties. It has the capacity to produce 30,000 tons of nickel metal and mixed sulfides containing 3,000 tons of nickel and 1,500 tons of cobalt. During 1996, Arboyne NL of Perth, Western Australia, secured an option to acquire 100% of Pacific Nickel Holdings. Arboyne planned to include alterations to the refinery to allow the use of higher grade imported ore and was considering adding a cobalt refinery to the complex (Mining Journal, 1997).

Russia.—Russian cobalt continued to contribute to Western supply in 1996. Russian cobalt is a byproduct of Russia's nickel industry. Nickel and cobalt production in Russia involves a complex flow of ores, flotation concentrates, precipitates, and mattes between various production sites. The main feed materials are domestic nickel-copper sulfide ores, nickel laterite ores from Russia and Kazakstan, and imported nickel- and cobalt-bearing secondary materials. Refined cobalt is produced at four locations: Norilsk Nickel Joint Stock Co. refineries at Norilsk in Siberia and Monchegorsk on the Kola Peninsula; the Ufaleynickel Joint Stock Co. refinery at Verkhniy Ufaley in the Ural Mountains; and the Yuzhuralnickel Joint Stock Co. refinery at Orsk, also in the Ural Mountains. In 1996, the Severonickel refinery in Monchegorsk stopped refining cobalt. Cobalt-bearing intermediate materials produced at Severonickel were sent to Ufaleynickel's refinery in the Urals to be toll refined (Starykh, 1996).

South Africa.—Cobalt was produced as a byproduct of South Africa's platinum industry. Rustenburg Base Metal Refiners Pty. Ltd. produced cobalt sulfate, and Impala Platinum Ltd. produced cobalt metal powder. Western Platinum Ltd. produced nickel sulfate containing minor amounts of cobalt.

Colossal Resources Corp. of Vancouver, British Columbia,

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began installation of a hydrometallurgical pilot plant to produce cobalt chemicals in Brakan, near Johannesburg. *(See Zambia section of this report.)*

Tanzania.—Sutton Resources Ltd. and BHP Minerals International Exploration Inc. renegotiated their exploration agreement regarding nickel-cobalt projects in northwestern Tanzania. Under the amended agreement, BHP relinquished its interest in the Kabanga deposit and in the southern portion of the Kagera reconnaissance area, but retained the right to earn an interest in the northern portion of Kagera. Sutton began discussions with prospective joint-venture partners for continued development of Kabanga and exploration of southern Kagera.

Uganda.—In July, Banff Resources, Ltd., of Vancouver, British Columbia, completed its acquisition of a 55% interest in Kasese Cobalt Co. Ltd. (KCCL). The remaining interest was held by Uganda's state-owned Kilembe Mines Ltd. KCCL has been involved in a project to build a refinery to recover cobalt from pyrite concentrates stockpiled during past production from the Kilembe copper mine. Banff planned to begin building the refinery at Kasese, southwestern Uganda, in early 1997 and begin cobalt production during the first quarter of 1998. The refinery was to use bioleaching followed by solvent extraction and electrowinning to produce 1,000 tons per year of cobalt cathode for about 10 years.

In addition to its interest in the Kasese project, Banff has an option agreement with Kilembe Mines Ltd. to earn a 65% interest in the Kilembe Mine by completing a feasibility study and arranging financing for production. During the year, Banff continued its exploration program at the mine and assessed the cobalt content of mine tailings in the Nyawamba River valley (Banff Resources Ltd., 1996).

Zaire.—During the year, Gécamines made several arrangements that would result in increased cobalt production from Zaire. In partnership with Union Minière, the Kasombo Mine west of Lubumbashi was reopened. Concentrates from Kasombo were toll refined at Gécamines Shituru refinery in Likasi. Approximately 3,000 tons of cobalt metal was expected to be produced from Kasombo over a 2-year period ending in late 1997 (Anyadike, 1996). Of this amount, more than 1,000 tons was expected to be produced in 1996 (Union Minière S.A., 1996).

Gécamines contracted with Union Minière's engineering subsidiary to improve cobalt recovery rates, improve some of the older purification methods, and upgrade the measuring and control equipment at the Shituru refinery. Once implemented, the improvements were expected to increase cobalt recovery by several hundred tons per year (Union Minière S.A., 1996).

In another project, Union Minière acquired approximately 28,000 tons of low-grade cobalt hydrates, containing an estimated 1,000 tons of recoverable cobalt. Union Minière shipped the hydrates to Union Mineral Concentrators Pty. in Roodepoort, near Johannesburg, South Africa, for initial processing. Once upgraded in South Africa, the hydrates would be refined at Union Minière's cobalt plant in Olen, Belgium (Union Minière S.A., 1996).

International Panorama Resource Corp. of Vancouver, British Columbia, purchased PTM Minerals Ltd. of the Cayman Islands and secured the rights to PTM's Kambove/Kakanda tailings project. The project is a joint venture with Gécamines to recover copper and cobalt from tailings located near Gécamines' Kambove and Kakanda concentrators. Gécamines estimated that the tailings were in excess of 61 million tons, with an average grade of 0.98% copper and 0.19% cobalt. This equates to nearly 600,000 tons of copper and 116,000 tons of cobalt. International Panorama was considering a leaching-solvent extraction-electrowinning process to treat the tailings. Production could begin within 2 years of completion of the feasibility study, which was scheduled for spring 1997 (International Panorama Resource Corp., 1996a, 1996b).

Consolidated Eurocan Ventures Ltd. of Vancouver, BC, Canada, acquired Lundin Holdings Ltd. and its joint-venture project with Gécamines to develop the Tenke Fungurume deposits northwest of Likasi in the Shaba Province's Copper Belt. Tenke Fungurume's "geological resources" reportedly total more than 222 million tons at 4.42% copper and 0.33% cobalt using a 1% copper equivalent cutoff grade. As part of the agreement with Gécamines, Tenke Fungurume Mining S.A.R.L. (TFM) was established to conduct the exploration, development, and mining of the Tenke Fungurume project. Ownership of TFM is 55% Lundin Holdings and 45% Gécamines. Consolidated Eurocan planned to complete a full feasibility study by the spring of 1997 and begin production within 4 years at an initial annual rate of 100,000 tons of copper and 8,000 tons of cobalt. The company proposed increasing annual production in three additional stages to a final 400,000 tons of copper by the year 2008 (Consolidated Eurocan Ventures Ltd., 1996).

In September, Gécamines received bids from six companies for a joint-venture project to recover copper and cobalt from flotation tailings accumulated during past production at Kolwezi. The economic viability of recovering copper and cobalt using a solvent extraction-electrowinning process would be investigated. An estimated 107 million tons of tailings averaging 1.34% copper and 0.70% cobalt was available for the project (South Atlantic Diamonds Corp., 1996). Two of the bidders were America Mineral Fields, Inc., of Hope, AR, and South Atlantic Resources Ltd. of Vancouver, British Columbia. America Mineral Fields and South Atlantic Resources each also qualified to bid on Gécamines' Ruashi-Etoile copper-cobalt project. The Ruashi-Etoile deposits, near Lubumbashi, were estimated to contain 62.5 million tons of ore at 3.45% copper and 0.46% cobalt (South Atlantic Diamonds Corp., 1996).

Zambia.—ZCCM produced 4,799 tons of cobalt metal between January and December 1996, an increase of 64% from the 2,934 tons produced in calendar year 1995 (Metal Bulletin, 1997). This return to more typical production levels was the result of mining higher grade ores at the Nchanga open pit.

In mid-1996, ZCCM adopted the recommendation of one of its advisors to privatize the company in two stages. In the first stage, majority interests in ZCCM assets would be sold to mining companies and other investors. ZCCM would retain

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minority interests in the operations, which would be managed by the incoming investors. The assets were grouped into nine packages for the sale, which was scheduled to be completed by the second half of 1997. In the second stage, all or part of the Government's shares in ZCCM would be offered to the Zambian public and to financial institutions worldwide. The second stage of privatization was scheduled for the first half of 1998.

In September, Colossal Resources Corp. of Vancouver, British Columbia, and Qasim Mining Enterprises Ltd. (QME) of Lusaka, Zambia, began treating smelter slag from ZCCM's Nkana division at its newly constructed pyrometallurgical plant in Kabwe. At the plant, electric arc furnaces were used to upgrade the slag to "white alloy" containing 8% to 10% cobalt, 25% copper, and 60% to 70% iron. The slag was being processed under a 25-year agreement with ZCCM. The agreement gives QME access to approximately 8.6 million tons of slag containing approximately 56,000 tons of cobalt and 80,000 tons of copper. In October, Colossal announced that it had acquired a hydrometallurgical pilot plant that would be used to convert white alloy to cobalt chemicals. The pilot plant was being installed and upgraded on a leased site in Brakpan, near Johannesburg, South Africa. Colossal established a new subsidiary, named SACOLCo Pty. Ltd., to operate the plant. After the process was tested in South Africa, Colossal planned to install a similar chemical facility at its Kabwe plant (Colossal Resources Corp., 1996a, 1996b).

Caledonia Mining Corp. of Toronto, Canada, explored for copper and cobalt in the southern extension of the copper belt. At its Nama cobalt oxide project, Caledonia increased the "inferred and indicated mineral resource" to 953 million tons at a 0.029% cobalt equivalent grade. Caledonia initiated a prefeasibility study on mining the Nama deposit using open pit methods, then treating the ore with an acid leach, solvent extraction, electrowinning process. Caledonia also announced a copper-cobalt oxide discovery in its Kadola licence area. The initial "inferred mineral resource" at Kadola West was calculated as 74 million tons at a grade of 0.95% copper equivalent (Caledonia Mining Corp., 1997).

Outlook

Cobalt supply is expected to continue to increase in the next few years. U.S. Government sales of cobalt from the NDS are expected to continue at the rate set each year under the annual materials plan until the amount authorized for disposal has been sold. Current producers are expected to expand their output, and many new producers hope to come on-stream in the next 5 to 10 years. The increased production will come from both newly mined ore and from the refining of stockpiled intermediate materials such as tailings and slags.

World cobalt demand is also expected to increase. Cobalt consumption by the superalloy industry will rise with the growth in production of commercial jet aircraft and land-based gas turbines for power generation. Significant growth is also expected for cobalt used to make rechargable batteries.

However, the growth in supply is expected to exceed the growth in demand. If that occurs, an oversupply situation would develop and prices would decrease. Lower prices would limit some of the potential future supply by discouraging production from higher cost operations and from projects where cobalt production is discretionary (dependent on cobalt price).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT COBALT STATISTICS 1/

(Metric tons cobalt content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Consumption:					
Reported	6,400 r/	6,430 r/	7,020 r/	7,030 r/	7,010
Apparent	6,590	7,310	8,470	8,640 r/	8,810
Imports for consumption	5,760	5,950	6,780	6,440	6,710
Exports	1,420	795	1,360	1,300	1,660
Stocks, December 31:					
Industry 2/	831 r/	810 r/	910 r/	818 r/	762
U.S. Government 3/	24,100	23,800	22,300	20,700	18,700
Price: Metal, per pound					
Average U.S. spot cathode 4/	$22.93	$13.79	$24.66	$29.21	$25.50
Yearend producer 5/	$18.00	$18.00	$25.00	$27.50	$27.50
World production:					
Mine	28,000 r/	21,900 r/	17,800 r/	23,800 r/	27,000 e/
Refinery	21,500 r/	16,600 r/	19,000 r/	22,100 r/	25,400 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Stocks held by cobalt processors and consumers.

3/ Defense Logistics Agency. Includes material committed for sale pending shipment.

4/ Price for 1992 is weighted average of weekly prices reported by Metals Week; prices for 1993-96 are annual average prices reported by Platt's Metals Week.

5/ Price established by La Générale des Carrières et des Mines and Zambia Consolidated Copper Mines Ltd.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
SALES AND SHIPMENTS 1/

(Metric tons cobalt content)

	1995	1996
Sales:		
Fiscal year 2/	1,890	1,810
Calendar year	2,740	1,020
Shipments:		
Fiscal year 2/	1,360	2,200
Calendar year	1,550	2,050

1/ Data are rounded to three significant digits.

2/ Twelve-month period ending Sept. 30 of year stated.

Source: Defense Logistics Agency.

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TABLE 3
U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT 1/ 2/

(Metric tons cobalt content)

	1995	1996
Consumption by end use:		
Steel:		
Stainless and heat resisting	38	38
Tool	146	95
Superalloys	2,940	3,230
Alloys (excludes steels and superalloys):		
Magnetic alloys	757	728
Welding materials (structural and hard-facing) 3/	287	284
Other alloys 4/	75 r/	65
Cemented carbides 5/	748	722
Chemical and ceramic uses:		
Catalysts	732	652
Driers in paints or related usage	770	733
Ground coat frit	196 r/	159
Pigments	172	191
Miscellaneous and unspecified 6/	164 r/	119
Total	7,030 r/	7,010
Consumption by form:		
Chemical compounds (organic and inorganic) 7/	1,830 r/	1,710
Metal	3,660	3,640
Purchased scrap	1,540	1,670
Total	7,030 r/	7,010
Stocks, December 31: 8/		
Chemical compounds (organic and inorganic) 7/	305 r/	275
Metal	384 r/	305
Purchased scrap	129 r/	182
Total	818 r/	762

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes estimates.
3/ Includes wear-resistant alloys.
4/ Includes nonferrous alloys.
5/ Includes diamond bit matrices, cemented and sintered carbides, and cast carbide dies or parts.
6/ Includes feed or nutritive additive, full-alloy steel, glass decolorizer, mill products made from metal powder.
7/ Includes oxides.
8/ Stocks held by cobalt processors and consumers.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM 1/

(Metric tons, unless otherwise specified)

		1995	1996
Metal: 2/			
Gross weight		5,530	5,760
Cobalt content 3/		5,530	5,760
Value	thousands	$325,000	$327,000
Oxides and hydroxides:			
Gross weight		808	824
Cobalt content 3/		582	593
Value	thousands	$34,300	$36,200
Other forms:			
Acetates:			
Gross weight		129	124
Cobalt content 3/		31	30
Value	thousands	$1,650	$1,760
Carbonates:			
Gross weight		80	61
Cobalt content 3/		37	28
Value	thousands	$2,310	$785
Chlorides:			
Gross weight		24	10
Cobalt content 3/		6	3
Value	thousands	$361	$102
Sulfates:			
Gross weight		940	1,070
Cobalt content 3/		254	288
Value	thousands	$11,500	$12,100
Total:			
Gross weight		7,510	7,850
Cobalt content 3/		6,440	6,710
Value	thousands	$376,000	$378,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys and waste and scrap.
3/ Estimated from gross weight.

Source: Bureau of the Census; minor adjustments by the U.S. Geological Survey.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY 1/

Country of origin	Metals 2/			Oxides and hydroxides			Other forms 3/			Total		
	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content 4/ (metric tons)	Value (thousands)
1995:												
Belgium	189	189	$13,500	217	156	$10,600	35	8	$552	441	354	$24,600
Brazil	30	30	1,660	–	–	–	–	–	–	30	30	1,660
Canada	993	993	60,700	66	47	3,070	18	8	486	1,080	1,050	64,300
China	18	18	1,090	12	8	149	–	–	–	30	27	1,240
Finland	658	658	41,300	266	192	10,900	898	241	11,100	1,820	1,090	63,300
France	34	34	2,970	19	14	1,600	(5/)	(5/)	3	54	48	4,580
Germany	147	147	9,430	2	1	83	–	–	–	149	148	9,520
Japan	14	14	841	10	7	280	(5/)	(5/)	8	24	21	1,130
Norway	1,510	1,510	93,700	–	–	–	–	–	–	1,510	1,510	93,700
Russia	649	649	30,900	90	65	2,450	177	59	3,260	915	772	36,600
South Africa	33	33	1,980	14	10	606	1	(5/)	14	48	43	2,600
United Kingdom	22	22	1,240	79	57	3,920	40	10	340	141	88	5,500
Zaire	656	656	34,800	–	–	–	–	–	–	656	656	34,800
Zambia	569	569	31,300	–	–	–	–	–	–	569	569	31,300
Other	3	3	146	33	24	623	3	1	16	39	27	786
Total	5,530	5,530	325,000	808	582	34,300	1,170	327	15,800	7,510	6,440	376,000
1996:												
Belgium	204	204	16,000	213	153	10,100	3	1	42	421	359	26,100
Brazil	47	47	2,200	–	–	–	–	–	–	47	47	2,200
Canada	927	927	54,300	60	43	2,580	28	13	585	1,010	983	57,500
Finland	561	561	34,100	408	294	16,700	1,160	311	13,500	2,130	1,170	64,300
France	29	29	3,040	20	14	1,760	–	–	–	49	43	4,800
Germany	100	100	7,640	2	1	152	–	–	–	102	102	7,790
Hong Kong	–	–	–	–	–	–	7	2	60	7	2	60
Japan	8	8	377	22	16	950	(5/)	(5/)	7	30	24	1,330
Norway	1,710	1,710	99,900	–	–	–	(5/)	(5/)	3	1,710	1,710	99,900
Russia	630	630	28,100	5	3	94	40	17	259	676	651	28,500
South Africa	10	10	601	4	3	182	–	–	–	14	13	783
United Kingdom	17	17	965	43	31	1,840	20	5	313	81	53	3,120
Zaire	396	396	21,200	–	–	–	–	–	–	396	396	21,200
Zambia	1,130	1,130	58,800	–	–	–	–	–	–	1,130	1,130	58,800
Other	(5/)	(5/)	45	47	34	1,730	4	1	23	51	35	1,800
Total	5,760	5,760	327,000	824	593	36,200	1,260	349	14,800	7,850	6,710	378,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Unwrought cobalt, excluding alloys; includes cobalt cathode and cobalt metal powder.
3/ Includes cobalt sulfates, cobalt chlorides, cobalt carbonates, and cobalt acetates.
4/ Estimated from gross weights.
5/ Less than 1/2 unit.

Source: Bureau of the Census; minor adjustments by the U.S. Geological Survey.

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TABLE 6
U.S. EXPORTS OF COBALT IN 1996, BY COUNTRY 1/ 2/

Country of destination	Metal 3/		Oxides and hydroxides		Acetates		Chlorides		Total	
	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Gross weight (metric tons)	Value 4/ (thou-sands)	Cobalt content 5/ (metric tons)	Value 4/ (thou-sands)
Australia	37	$370	6	$231	5	$195	--	--	42	$796
Belgium	189	14,700	9	170	--	--	--	--	196	14,900
Brazil	17	557	14	618	12	220	1	$16	30	1,410
Canada	145	5,360	44	855	19	173	1	13	182	6,400
Chile	(6/)	7	10	216	--	--	--	--	8	223
Colombia	--	--	3	103	3	82	--	--	3	185
Dominican Republic	--	--	--	--	1	14	3	43	1	58
France	12	700	9	298	--	--	--	--	19	999
Germany	47	2,370	3	128	--	--	--	--	50	2,500
Grenada	--	--	--	--	--	--	(6/)	5	(6/)	5
Guatemala	--	--	1	9	(6/)	3	4	44	2	57
Hong Kong	57	2,920	22	608	--	--	--	--	73	3,520
Indonesia	(6/)	4	5	331	--	--	--	--	4	335
Jamaica	--	--	(6/)	10	(6/)	4	1	10	(6/)	24
Japan	323	16,700	63	1,540	24	575	--	--	374	18,800
Korea, Republic of	18	837	14	352	4	95	2	28	30	1,310
Mexico	24	1,210	61	2,530	331	2,110	--	--	147	5,850
Netherlands	239	11,900	44	1,270	6	85	--	--	272	13,300
Taiwan	1	90	8	123	11	196	--	--	10	409
United Kingdom	134	5,180	4	56	10	13	--	--	138	5,250
Venezuela	--	--	5	221	3	41	--	--	4	262
Other	62	2,590	20	514	5	76	(6/)	3	77	3,180
Total	1,310	65,500	346	10,200	433	3,880	13	162	1,660	79,800

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.
3/ Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.
4/ Free alongside ship (f.a.s.) value.
5/ Estimated from gross weight.
6/ Less than 1/2 unit.

Source: Bureau of the Census; minor adjustments by the U.S. Geological Survey.

TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY
DECEMBER 31, 1996 1/

(Metric tons, cobalt content)

Country	
Belgium 2/	1,200
Brazil	300
Canada 2/	4,400
China e/	500
Finland e/ 2/	4,700
France 3/	600
Japan 2/	480
Morocco	300
Norway	3,700
Russia e/	8,000
South Africa e/ 4/	750
United States 5/	900
Zaire	18,000
Zambia	5,000
Total	48,800

e/ Estimated.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes oxide and salts.
3/ Cobalt chloride.
4/ Includes sulfate.
5/ Standby capacity.

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TABLE 8
COBALT: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1992	1993	1994	1995	1996 e/
Albania e/ 4/	20	10	10	–	–
Australia e/ 5/	1,600	1,800	2,200	2,200 r/	2,300
Botswana 6/	208	205	225	270 r/	410 7/
Brazil e/	400	400	400	400	400
Canada 8/	5,102	5,108	4,265	5,339 r/	5,803 p/
China e/	260	240	270	980	800
Cuba e/ 9/	1,150	1,060	972	1,561 7/	1,968 7/
Kazakstan e/ 10/	1,000	600	300	300	300
Morocco 11/	461	397	440	548 r/	565 7/
New Caledonia e/ 12/	800	800	800	800	800
Russia e/	4,000	3,500	3,000	3,500	3,300
South Africa e/	350	350	370 r/	290 r/	350
Zaire 11/	5,700	2,459	826 e/	1,647	2,000
Zambia 11/ 13/	6,910	4,840	3,600 r/	5,908 r/	7,900
Zimbabwe e/	80	90	100	100	90
Total	28,000 r/	21,900 r/	17,800 r/	23,800 r/	27,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 1997. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from copper, nickel, platinum, or zinc operations. Morocco was the only country where cobalt was mined as a primary product.

3/ In addition to the countries listed, Bulgaria, Germany, Indonesia, and Poland are known to produce ores that contain cobalt, but information is inadequate for reliable estimates of output levels. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

4/ Calculated from reported and estimated weight of nickeliferous ore.

5/ Figures represent quantities of cobalt contained in intermediate metallurgical products (cobalt sulfide, nickel-cobalt sulfide, nickel concentrate, and nickel matte) produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia was estimated as follows, in metric tons: 1992--1,270; 1993--1,320; 1994--1,270; 1995--800 (revised); and 1996--900 (reported).

6/ Reported cobalt content of pelletized nickel-copper matte.

7/ Reported figure.

8/ Figures represent the assay content of cobalt in concentrates produced. The cobalt content of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper-cobalt matte shipped to Norway for refining, was reported as follows, in metric tons: 1992--2,223; 1993--2,150; 1994--1,846; 1995--2,016 (revised); and 1996--2,190.

9/ Determined from reported nickel-cobalt content of sulfide production. Data not comparable with those prior to 1990.

10/ Figures represent estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be as follows, in metric tons: 1992-93--not available; 1994--1,394; 1995--1,400; and 1996--1,400.

11/ Cobalt content of concentrates.

12/ Series represents estimated recoverable content of ores and intermediate metallurgical products exported from New Caledonia to France. Estimated cobalt content of total ores mined is 6,000 metric tons per year.

13/ Fiscal year beginning Apr. 1 of that stated. Cobalt content of ore milled was as follows, in metric tons: 1992--11,370; 1993--9,480; 1994--6,747; 1995--8,849 (revised); and 1996--12,000 (estimated).

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TABLE 9
COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, cobalt content)

Country 3/	1992	1993	1994	1995	1996
Albania: Oxide e/	3	1	--	--	--
Brazil: Metal e/	240	240	240	180	180
Canada: Metal (including metal powder and oxide)	2,210	2,695	2,971	3,269 r/	3,552 p/
China: Metal e/	220	190	200	240 r/	200
Finland (metal powder and salts)	2,100	2,200	3,000	3,610	4,160
France: Chloride	120	144	146	161	174
Japan: Metal	105	191	161	227	222
Norway: Metal	2,293	2,414	2,823	2,804	3,098
Russia: Unspecified	4,100 r/	3,700 r/	4,340 r/	4,450 r/	4,200
South Africa:					
Metal (powder) e/	65	71 r/	44 r/	32 4/	42
Sulfate e/	169	172 r/	214 r/	158 4/	200
Total	234	243 r/	258 r/	190	242
Zaire: Metal 5/	5,049	831	2,329	3,441	4,200 e/
Zambia: Metal 6/	4,797	3,705	2,482	3,577	5,126
Grand total	21,500 r/	16,600 r/	19,000 r/	22,100 r/	25,400 r/
Of which:					
Metal	15,000	10,300	11,300 r/	13,800 r/	16,600
Salts 7/	292	317 r/	360 r/	319	374
Unspecified	6,200 r/	5,900 r/	7,340 r/	8,060 r/	8,360

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data through June 18, 1997. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

3/ In addition to the countries listed, Belgium, Germany, and Slovakia may recover cobalt from imported materials, but production is not reported; available information is inadequate to make reliable estimates of production.

4/ Reported figure.

5/ Excludes production of cobalt in white alloy, matte, and slag that would require further refining.

6/ Fiscal years beginning Apr. 1 of that stated.

7/ Includes oxide.

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COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

Columbium (niobium-Nb) is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. Columbium is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Acceptable substitutes are available for some columbium applications, but in most cases they are less desirable.

Tantalum (Ta) is a refractory metal that is ductile, easily fabricated, has a high melting point, is highly resistant to corrosion by acids, and is a good conductor of heat and electricity. Tantalum is also critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications.

Domestic columbium and tantalum resources are of low grade. Some are mineralogically complex, and most are not currently commercially recoverable. The last significant mining of columbium and tantalum was during the Korean conflict when increased military demand resulted in columbium and tantalum ore shortages.

The United States continued to be dependent on imports of columbium and tantalum materials. Brazil continued as the major source for columbium imports, and Australia was the major source for tantalum imports. Columbium and tantalum price quotations were unchanged for the year. The Generalized System of Preferences (GSP), which expired on July 31, 1995, was extended to May 31, 1997. There was an overall increase in reported consumption of columbium in the form of ferrocolumbium and nickel columbium. Tantalum consumption was down for the year, owing to a drop in demand from the electronics industry.

Legislation and Government Programs

The high degree of import reliance for columbium and tantalum is a major concern of the United States. Summaries of important columbium and tantalum statistics are shown in tables 1 and 2, respectively. *(See tables 1 and 2.)*

To ensure a supply of columbium and tantalum during an emergency, goals for both materials have been established for the National Defense Stockpile (NDS). As of September 30, 1996, NDS overall goal for the columbium group was 982,000 kilograms, and the overall goal for the tantalum group was 1.05 million kilograms. *(See table 3.)*

In October, the interagency National Defense Stockpile Market Impact Committee announced that it was seeking public comment on the potential market impact of the U.S. Department of Defense's (DOD) proposed disposals of materials from the NDS in the Federal Register. The Committee is comprised of representatives from the Departments of Commerce, State, Agriculture, Defense, Energy, Interior, Treasury, and the Federal Emergency Management Agency. The DOD proposed to dispose of about 27,200 kilograms of ferrocolumbium in fiscal year 1997 and about 45,400 kilograms in fiscal year 1998. Additionally, the DOD proposed to dispose of about 907 kilograms of tantalum carbide powder, about 45,400 kilograms of tantalum minerals, and about 9,070 kilograms of tantalum oxide in each of fiscal years 1997 and 1998. The deadline for comments to the Committee was November 1, 1996 (U.S. Department of Commerce, 1996). Subsequently, in December, the DOD presented a consolidated Annual Materials Plan for fiscal year 1997 stockpile disposals. The plan was said to be in response to requests from DOD customers. The maximum quantity of materials permitted for disposal under the plan included the 27,200 kilograms of ferrocolumbium, 907 kilograms of tantalum carbide powder, 45,400 kilograms of tantalum minerals, and 9,070 kilograms of tantalum oxide (Defense National Stockpile Center, 1996).

On August 20, 1996, the President signed the Small Business Job Protection Act of 1996, which contained provisions entitled the GSP Renewal Act of 1996. The Act provides that GSP duty free treatment will apply to eligible articles from designated beneficiary countries that are entered, or withdrawn from warehouse, for consumption on or after October 1, 1996, through May 31, 1997. Additionally, GSP duty free treatment will have certain retroactive applications to articles entered after July 31, 1995, and before October 1, 1996 (U.S. Department of the Treasury, 1996). Under GSP, the United States grants duty free access to goods from qualifying developing countries and territories. In 1996, U.S. imports for selected columbium and tantalum materials ranged from duty free to 5.1% ad valorem for most-favored-nation (MFN) status and from duty free to 45% ad valorem for non-MFN status.

Production

Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey from the annual voluntary domestic survey for ferroalloys. However, ferrocolumbium production data for 1996 were incomplete at the time this report

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was prepared.

There was no domestic mineral production of either columbium or tantalum in 1996. However, there were two processors of columbium- and tantalum-bearing source materials that were integrated from raw material processing to columbium and tantalum end products: Cabot Corp., Boyertown, PA, for columbium and tantalum processing, and Shieldalloy Metallurgical Corp., Newfield, NJ, dedicated solely to columbium processing. H.C. Starck GmbH & Co. KG, with plants in Newton, MA, and Gurnee, IL, was a major supplier of tantalum and columbium products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, a subsidiary of Allegheny Teledyne Inc., Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and tantalum carbides.

Vishay Intertechnology Inc., Malvern, PA, announced that the company had formed a partnership with the Eisenberg Group of Companies. The new partnership reportedly signed a cooperation agreement with the China National Non-Ferrous Metals Industry Corp., a Chinese Government agency. The agreement provides for the comprehensive development of the tantalum industry in China including the mining and refining of tantalum ore and the production of tantalum capacitors in China through several joint ventures. Additionally, Vishay, the largest U.S. producer of passive electronic components, including capacitors, was pursuing the acquisition of Kemet Corp., Greenville, SC, the largest U.S. manufacturer of tantalum capacitors (American Metal Market, 1996a; Ryan's Notes, 1996; Tantalum-Niobium International Study Center, 1996).

According to its annual report, Kennametal Inc., Latrobe, PA, reported that the company's board of directors approved a plan in January to build a $20 million facility in Shanghai, China. The facility will be used to manufacture cemented carbide metalcutting tools (Kennametal Inc., 1996).

On August 15, Allegheny Ludlum Corp., Pittsburgh, PA, and Teledyne, Inc., Los Angeles, CA, combined to form Allegheny Teledyne Inc., headquartered in Pittsburgh, PA. Allegheny Ludlum shareholders received one share of Allegheny Teledyne common stock for each of their Allegheny Ludlum common shares, while Teledyne stockholders received 1.925 shares of Allegheny Teledyne common stock for each of their Teledyne common shares. Allegheny Teledyne, a group of technology-based manufacturing businesses, will serve worldwide customers with specialty metals for consumer, industrial and aerospace applications; and commercial and government-related aerospace and electronics products. Allegheny Teledyne's Wah Chang division, Albany, OR, is a leading producer of reactive and refractory metals, including columbium and its alloys (Allegheny Teledyne Inc., 1996).

Consumption

Overall reported consumption of columbium as ferrocolumbium and nickel columbium increased by about 4%. *(See table 4.)* Consumption of columbium by the steelmaking industry increased by about 5%, with the percentage of columbium usage per ton of steel produced up by about 4%. Columbium consumption was up or relatively unchanged in all major reported steel end-use categories. Demand for columbium in superalloys increased to about 509,000 kilograms. That portion used in the form of nickel columbium rose to about 350,000 kilograms.

Overall consumption of tantalum was down from that of 1995. Industry sources indicated that factory sales of tantalum capacitors decreased by about 15%, the first decline in sales since 1989. A weaker demand for personal computers and some telecommunications equipment, such as portable telephones and the liquidation of inventories accumulated in 1995 influenced the drop in sales.

Columbium.—Columbium and niobium are synonymous names for the chemical element with atomic number 41; columbium was the first name given, and niobium was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity relatively well, has a high melting point (about 2,470 °C), is readily fabricated, and is highly resistant to many chemical environments.

Columbium, in the form of ferrocolumbium, is used worldwide, principally as an additive to improve the strength and corrosion resistance of steel. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in nickel-, cobalt-, and iron-base superalloys for applications such as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten carbide-based material. It is usually used with carbides of metals such as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of high-purity ferrocolumbium, nickel columbium, columbium metal, and columbium carbide.

Tantalum.—The major end use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. Applications for tantalum capacitors include computers, communication systems, instruments and controls for aircraft, missiles, ships, and weapon systems. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf-life. Because of its high melting point (about 3,000 °C), good strength at elevated temperatures and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are employed in aerospace structures and jet engine components. Tantalum carbide, used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in cemented-carbide cutting tools, wear-resistant parts, farm tools, and turning and boring tools. Because of tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used in the chemical industry in applications such as heat exchangers, evaporators, condensers, pumps, and liners for reactors and tanks.

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Prices

A published price for pyrochlore concentrates was not available. A price for Brazilian pyrochlore has not been available since 1981 when exports were stopped, and the published price for pyrochlore produced in Canada was suspended in early 1989. The Platt's Metals Week price for regular-grade ferrocolumbium, produced from pyrochlore concentrates, was unchanged throughout the year at $6.58 per pound of contained columbium.

The Metal Bulletin price for columbite ore, on the basis of a minimum 65% contained Nb_2O_5 and Ta_2O_5, remained unchanged at a range of $2.80 to $3.20 per pound. For the year, the Metals Week price for columbium oxide was $8.17 per pound of oxide; the price for high-purity ferrocolumbium containing 62% to 68% columbium was $18.50 per pound of contained columbium, f.o.b. shipping point; the price for nickel columbium was $20.50 per pound of contained columbium; and the price for columbium metal was at a range of $30 to $50.

The Metals Week spot price for tantalite ore, on the basis of contained Ta_2O_5, f.o.b. U.S. ports, remained unchanged at a range of $27 to $28.50 per pound. For the year, the Metal Bulletin price for tantalite was at a range of $28 to $31.50 per pound of contained Ta_2O_5. The Metal Bulletin price for tantalite produced at the Greenbushes Mine in Australia, on the basis of 40% contained Ta_2O_5, was $40 per pound. Industry sources indicated that the average selling prices for some tantalum products were as follows (per pound of contained tantalum): powder, $100 to $180; wire, $170 to $250; and sheet, $100 to $150. Tantalum oxide was selling at an average of $40 to $90 per pound of oxide, and the average selling price for tantalum carbide was $45 to $60 per pound.

Foreign Trade

Data for exports and imports are summarized in table 5. Net trade for columbium and tantalum continued at a deficit. Overall trade value for exports was up by about 16%, with total volume down by more than 20%. For imports, overall trade value was down slightly with total volume down by more than 20%. *(See table 5.)*

Imports for consumption of columbium ores and concentrates were down, owing to the continued decrease in the volume of imports from Canada. *(See table 6.)* Imports at an average grade of approximately 47% Nb_2O_5 and 17% Ta_2O_5 were estimated to contain about 75,000 kilograms of columbium and about 25,000 kilograms of tantalum.

Imports for consumption of tantalum ores and concentrates increased by more than 10%, with imports from Australia accounting for more than 50% of total quantity and total value. *(See table 7.)* Imports at an average grade of approximately 40% Ta_2O_5 and 26% Nb_2O_5 were estimated to contain about 335,000 kilograms of tantalum and about 210,000 kilograms of columbium.

Imports for consumption of synthetic tantalum-columbium concentrates totaled 30,000 kilograms valued at $1.1 million compared with 100,000 kilograms valued at $872,000 in 1995. These figures are not included in the salient statistics data.

The schedule of tariffs applied during 1996 to U.S. imports of selected columbium and tantalum materials is found in the U.S. International Trade Commission's (USITC's) 1996 Harmonized Tariff Schedule of the United States, USITC Publication 2937. Brazil remained the major source for U.S. columbium imports, accounting for more than 60% of the total, and Australia was the major source for U.S. tantalum imports, accounting for more than 30% of the total. *(See figures 1 and 2.)*

World Review

Industry Structure.—Principal world columbium and tantalum raw material and product producers are shown in tables 8 and 9, respectively. Brazil and Canada remained the major producers of columbium mineral concentrates, while tantalum mineral concentrates continued to be produced mainly in Australia, Brazil, and Canada. Annual world production of columbium and tantalum mineral concentrates, by country, is given in table 10. *(See tables 8, 9, and 10.)*

Australia.—For its fiscal year ending June 30, 1996, Gwalia Consolidated Ltd., the world's largest producer of tantalum concentrates, reported that tantalum oxide produced in tantalum concentrates at its Greenbushes Mine, southwest Western Australia, was about 272 tons, a record level, compared with about 211 tons in 1995. Mill ore throughput increased by 20% with higher recoveries to final product. Sales of tantalum oxide in concentrate produced at the Greenbushes operation increased to a record 251 tons. During the 3 months ending June 30, 1996, Gwalia finalized purchase of the Wodgina Tantalum Mine and surrounding tenements for a reported $14.5 million. Wodgina is 100 kilometers inland from Port Hedland, northwest Western Australia. Mining of ore at the Mount Cassiterite open pit operation is performed by contractors on a 3-month campaign basis per year. Tantalum concentrate produced at Wodgina is shipped to the Greenbushes operation for upgrading. Gwalia reported that the company had renegotiated and extended sales contracts for all tantalum production at Greenbushes and Wodgina to the year 2000. Sale of the concentrate over the 4-year period will secure the company revenue of $180 million (Gwalia Consolidated Ltd., 1996).

Brazil.—Brazil's production of columbium oxide in concentrates decreased to about 19,300 tons — 15,700 tons produced by Cia. Brasileira de Metalurgia e Mineracao (CBMM) and 3,600 tons produced by Mineracao Catalao de Goias S.A. CBMM, the world's largest columbium producer, was reported to have the capacity to produce 24,000 tons of steelmaking-grade ferrocolumbium, 600 tons of high-purity ferrocolumbium, 600 tons of nickel columbium, and 2,000 tons of high-purity columbium oxide. Brazil's consumption of columbium, based on contained columbium oxide, totaled 930 tons, compared with 1,020 tons in 1995 (The TEX Report, 1997).

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In January, CBMM announced that the company would increase the price for ferrocolumbium and columbium oxide, the first price increase by CBMM since July 1989. The price increase was effective January 1, owing to the rising costs of reduction agents such as aluminum, increased labor costs, a 4.5% tax on columbium exports, and capital investments to improve production processes (Metal Bulletin, 1996a).

Canada.—Teck Corp. reported that production of columbium oxide contained in concentrate at the Niobec Mine near Chicoutimi, Quebec, decreased to about 3.32 million kilograms. Niobec is a 50-50 joint venture between Teck, operator, and Cambior Inc., product marketing. Ore milled increased to 810,000 tons, as the mill operated on the average of 2,220 tons of ore per day. Average recovery was 58.8% with Nb_2O_5 grade of concentrate at 70%. Teck reported that Niobec ore reserves are sufficient for another 15 years of mine life. In 1997, Niobec is forecast to produce about 2.18 million kilograms of columbium, with capital expenditures projected at $4.5 million. The expenditures will include $3 million for the first phase development of a lower ore block (increasing hoist system capacity and establishing ventilation and shaft access). This development along with a second phase to deepen the shaft, to be completed by mid-1999, is expected to add 4 million tons to mine ore reserves (Teck Corp., 1996).

Since midyear 1992, tantalum mining at the Bernic Lake, Manitoba, tantalum operation has remained suspended. However, about 59 tons of tantalum oxide contained in concentrate was produced from tailings retreatment in 1996.

Germany.—H.C. Starck GmbH & Co. KG, Goslar, a wholly owned subsidiary of Bayer AG, Leverkusen, acquired a majority holding in Thai Tantalum Co. Ltd., Map Ta Phut, Thailand, a tantalum source material processing plant that produces potassium fluotantalate and tantalum metal powder. The acquisition improves Starck's access to raw materials and markets for the company's products in Southeast Asia (American Metal Market, 1996b; Metal Bulletin, 1996c). The acquisition also included a tantalum capacitor-grade powder facility in Gurnee, IL.

Japan.—Japan's production of ferrocolumbium was idle compared with 39 tons produced in 1995. Domestic consumption of ferrocolumbium totaled about 4,620 tons compared with about 4,430 tons in 1995. Ferrocolumbium imports totaled about 4,760 tons (The TEX Report, 1997).

Japan's demand for tantalum, in the form of powder, compounds, and tantalum products, was about 322 tons compared with about 315 tons in 1995. Japanese imports of these products in 1996 totaled about 108 tons. Japan's production of tantalum capacitors was about 5.5 billion units compared with about 5.8 billion units in 1995. Japan's shipments of tantalum capacitors in 1996 totaled about 5.4 billion units (Roskill's Letter from Japan, 1997).

Mozambique.—Cabot Corp., Boston, MA, in a venture with Madal S.A.R.L. and Lydenburg Exploration, South Africa, was conducting a feasibility study on reopening the Morrua tantalum property in Mozambique, 340 kilometers from Quelimane. Completion of the study is expected in early 1997. Morrua was a major tantalum producing property during the period from the late 1950's to the early 1980's (Tantalum-Niobium International Study Center, 1996).

Russia.—Metallurg Inc., New York, NY, a supplier of speciality alloys and metals, announced in August that the company had acquired an undisclosed share holding in Solikamsk Magnesium Works, which is in the Perm region of Russia. Solikamsk produces magnesium products, rare earth compounds, titanium oxide, and the company produces about 55 to 60 tons of tantalum oxide and 700 to 750 tons of columbium oxide per year. The holding reportedly gives Metallurg better access to Solikamsk's products for either consumption within Metallurg's group of companies or for distribution elsewhere (Metal Bulletin, 1996b).

Outlook

Columbium.—The principal use for columbium remains as an additive in steelmaking, which annually accounts for more than 80% of reported consumption in the United States. The trend of columbium demand, domestically and globally, will continue to follow closely that of steel production. The reader is referred to the outlook section of the Iron and Steel Annual Mineral Industry Surveys for discussion on the outlook for the steel industry. Industry sources indicate that the annual growth rate for world steel consumption through the year 2000 will be almost 2%. Most growth will occur in China, other Asian countries, with the exception of Japan, and in Latin America. Asia was projected to account for 47% of world steel consumption by the year 2000 (Iron & Steelmaker, 1996).

Tantalum.—In 1996, U.S. apparent consumption of tantalum totaled about 490,000 kilograms compared with about 515,000 kilograms in 1995. For the past decade, more than 60% of the tantalum consumed has been used to produce electronic components, mainly tantalum capacitors. Industry sources indicate that worldwide consumption of tantalum capacitors is expected to increase to about 25 billion units by the year 2000, a 14% annual growth rate. During this period, the annual per-unit requirement of tantalum powder and wire for tantalum capacitors is expected to decline at an annual rate of 6% and 5%, respectively. However, the overall trend is for increased tantalum consumption. Thus, world consumption in this sector is expected to be about 953,000 kilograms of tantalum by the year 2000. Tantalum demand in the cemented carbide sector will continue to be limited by the use of coatings, which prolong tool life, and by efforts to achieve near-to-shape form through powder metallurgy to minimize subsequent machining. Growth in this sector is expected to be less than 5% annually.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT COLUMBIUM STATISTICS 1/

(Thousand kilograms of columbium content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Mine production of columbium-tantalum concentrates	(2/)	--	--	--	--
Releases from Government excesses	--	--	--	--	--
Production of ferrocolumbium	NA	NA	NA	NA	NA
Exports: Columbium metal, compounds, alloys (gross weight)	NA	NA	NA	NA	NA
Imports for consumption:					
Mineral concentrates e/	1,230	1,210	1,480	615	285
Columbium metal and columbium-bearing alloys e/	1	111	171	257	322
Ferrocolumbium e/	2,450	2,190	2,590	3,580	2,970
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium e/	2,460	2,470	2,750	2,900	3,020
Apparent e/	3,500	3,500	3,700	3,800	3,800
Prices:					
Columbite, dollars per pound 3/	2.83	2.67	2.60	2.97	3.00
Pyrochlore, dollars per pound 4/	2.75	2.75	NA	NA	NA
World: Production of columbium-tantalum concetrates e/	15,300	12,400	15,400	18,000 r/	16,000

e/ Estimated. r/ Revised. NA Not available.
1/ Data are rounded to three significant digits, except prices.
2/ A small unreported quantity was produced.
3/ Average value, contained pentoxides for material having a columbium pentoxide to tantalum pentoxide ratio of 10 to 1.
4/ Average value, contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

(Thousand kilograms of tantalum content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Mine production of columbium-tantalum concentrates	(1/)	(1/)	--	--	--
Releases from Government excesses	--	--	--	--	--
Exports:					
Tantalum ores and concentrates (gross weight) 2/	17	11	23	1	53
Tantalum metal, compounds, alloys (gross weight)	136	235	242	281	342
Tantalum and tantalum alloy powder (gross weight)	61	57	46	41	26
Imports for consumption:					
Mineral concentrates e/	420	390	310	300	360
Tantalum metal and tantalum-bearing alloys 3/	14	67	73	181	203
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Apparent e/	375	410	430	515	490
Prices:					
Tantalite, dollars per pound 4/	28.19	26.41	26.24	26.98	27.75
World: Production of columbium-tantalum concentrates e/	399	310	333	362 r/	383

e/ Estimated. r/ Revised. NA Not available.
1/ A small unreported quantity was produced.
2/ Includes reexports.
3/ Exclusive of waste and scrap.
4/ Average value, contained tantalum pentoxides.

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TABLE 3
COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT
INVENTORIES AS OF DECEMBER 31, 1996 1/

(Thousand kilograms of columbium or tantalum content)

Material	Stockpile goals	Disposal authority	National Defense Stockpile inventory			
			Uncommitted 2/			
			Stockpile-grade	Nonstockpile-grade	Total	Committed
Columbium:						
Concentrates	--	--	444	343	786	--
Carbide powder	--	--	10	--	10	--
Ferrocolumbium		422	385	151	535	--
Metal ingots	--	--	73	--	73	--
Total	982 3/	422	911	493	1,400	--
Tantalum:						
Minerals	--	340	681	454	1,140	--
Carbide powder	--	--	13	--	13	--
Metal:						
Capacitor grade	--	--	73	(4/)	73	--
Ingots	--	--	46	--	46	--
Oxide	--	18	74	--	74	--
Total	1,050 3/	358	887	454	1,340	--

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ The stockpile also contained an uncommitted inventory of 65,000 kilograms in tantalum metal ingots with status (inventory) not yet determined.
3/ Overall goals for the columbium and tantalum groups as of Sept. 30, 1996.
4/ 45 kilograms.

Source: Defense Logistics Agency, Defense National Stockpile Center.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF
FERROCOLUMBIUM AND NICKEL COLUMBIUM
IN THE UNITED STATES 1/

(Kilograms of contained columbium 2/)

End use	1995	1996
Steel:		
Carbon	917,000	1,030,000
Stainless and heat-resisting	408,000	413,000
Full alloy	(3/)	(3/)
High-strength low-alloy	1,050,000	1,050,000
Electric	--	--
Tool	(4/)	(4/)
Unspecified	5,060	6,880
Total	2,380,000	2,500,000
Superalloys	506,000	509,000
Alloys (excluding alloy steels and superalloys)	(5/)	(5/)
Miscellaneous and unspecified	9,820	7,110
Total	2,900,000	3,020,000
Stocks, Dec. 31:		
Consumer	NA	NA
Producer 6/	NA	NA
Total	NA	NA

NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes columbium and tantalum in ferrotantalum-columbium, if any.
3/ Included with "Steel: High-strength low alloy."
4/ Included with "Steel: Unspecified."
5/ Included with "Miscellaneous and unspecified."
6/ Ferrocolumbium only.

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TABLE 5
U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS 1/

(Thousand kilograms, gross weight, and thousand dollars)

Class	1995 Quantity	1995 Value	1996 Quantity	1996 Value	Principal destinations and sources, 1996
Exports: 2/					
Columbium:					
Ores and concentrates	96	869	11	185	United Kingdom 2, $65; Japan 1, $49; Korea, Republic of 2, $44; Hong Kong 4, $14; Brazil 2, $13.
Ferrocolumbium	529	4,450	254	1,490	Netherlands 133, $550; Korea, Republic of 50, $350; Mexico 27, $265; Australia 16, $147; Venezuela 12, $119; Brazil 14, $43.
Tantalum:					
Synthetic concentrates	1	19	38	192	United Kingdom 34, $68; Taiwan 1, $66; Japan 1, $35; Philippines 2, $16; Austria 1, $7.
Ores and concentrates	1	36	53	572	Israel 8, $178; Brazil 19, $148; China 13, $91; Hong Kong 3, $90; Russia 9, $58.
Unwrought and waste and scrap	143	5,990	152	7,420	Germany 54, $3,900; China 85, $1,810; United Kingdom 7, $1,070; Japan 3, $395; Netherlands 2, $143; Kazakstan, 1, $96.
Unwrought powders	41	11,000	26	7,860	Japan 8, $2,510; Germany 7, $2,380; France 6, $1,640; United Kingdom 4, $1,180; Taiwan (3/), $65; Portugal (3/), $29.
Unwrought alloys and metal	27	8,790	91	24,900	Israel 53, $12,000; United Kingdom 15, $6,190; France 13, $3,420; Taiwan 3, $1,070; Barbados 2, $826; Austria 2, $487.
Wrought	111	33,000	99	32,100	Japan 34, $15,300; Germany 21, $5,850; United Kingdom 8, $2,980; France 6, 2,790; Canada 22, $2,250; Sweden 1, $522.
Total	XX	64,200	XX	74,700	Japan $18,300; Germany $12,500; Israel $12,400; United Kingdom $11,600;
Imports for consumption:					
Columbium:					
Ores and concentrates	1,040	6,580	224	1,700	Russia 92, $921; Nigeria 93, $513; Canada 38, $201; United Kingdom (3/), $19; China 1, $14; Italy (3/), $14.
Oxide	1,320	20,200	901	16,300	Brazil 566, $9,030; Germany 144, $5,270; Russia 156, $1,540; Finland 20, $197; Thailand 10, $154; China 4, $108.
Ferrocolumbium	5,510	45,000	4,570	42,100	Brazil 3,360, $29,300; Canada 1,160, $12,000; Germany 28, $583; France 27, $249; Japan (3/), $11.
Unwrought alloys, metal, and powder	257	5,380	322	8,310	Germany 170, $3,570; Brazil 58, $1,590; Kazakstan 46, $1,520; Russia 40, $1,350; Estonia 7, $261; United Kingdom 1, $8.
Tantalum:					
Synthetic concentrates	100	872	30	1,090	China 30, $1,080; Germany (3/), $14.
Ores and concentrates	1,020	23,400	1,130	26,400	Australia 593, $14,900; Ethiopia 70, $2,910; Brazil 134, $2,280; Rwanda 71, $1,260; Burundi 60, $1,190; Thailand 60, $997; Russia 79, $872; China 23, $735.
Unwrought waste and scrap	364	28,500	279	22,500	Japan 69, $6,870; Kazakstan 29, $3,810; Lithuania 25, $ 2,500; Germany 43, $2,440; United Kingdom 19, $1,600; Russia 11, $1,070; France 10, $911; China 9, $902.
Unwrought powders	101	21,600	125	30,000	Thailand 55, $11,800; Japan 27, $8,770; China 26, $6,270; France 6, $1,930; Russia 5, $573; Kazakstan 3, $398.
Unwrought alloys and metal	75	9,590	67	11,000	Kazakstan 26, $3,890; Germany 21, $2,990; France 10, $1,790; China 4, $1,160; Israel 3, $630; Japan 1, $386; United Kingdom 1, $122.
Wrought	5	1,500	11	2,820	China 8, $1,550; Austria 1, $352; United Kingdom (3/), $285; Japan (3/), $189; Germany 1, $180; Switzerland (3/), $131; Russia 1, $69.
Total	XX	162,000	XX	162,000	Brazil $42,200; Japan $16,200; Germany $15,300; Australia $14,900; Thailand $13,700; Canada $12,200; China $11,800.

XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.
3/ Less than 1/2 unit.

Sources: Bureau of the Census and U.S. Geological Survey.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY 1/

(Thousand kilograms and thousand dollars)

Country	1995		1996	
	Gross weight	Value	Gross weight	Value
Brazil	27	130	--	--
Canada	851	5,400	38	201
China	--	--	1	14
Estonia	1	53	--	--
Germany 2/	(3/)	13	(3/)	13
Italy 2/	--	--	(3/)	14
Japan 2/	--	--	(3/)	2
Nigeria	117	618	93	513
Russia	41	355	92	921
United Kingdom 2/	2	10	(3/)	19
Total	1,040	6,580	224	1,700

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Presumably country of transshipment rather than original source.
3/ Less than 1/2 unit.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY 1/

(Thousand kilograms and thousand dollars)

Country	1995		1996	
	Gross weight	Value	Gross weight	Value
Australia	323	10,700	593	14,900
Belgium 2/	20	403	2	106
Brazil	170	3,390	134	2,280
Burundi	123	2,260	60	1,190
China	69	1,270	23	735
Ethiopia	7	263	70	2,910
Germany 2/	22	423	1	3
Japan 2/	(3/)	12	(3/)	7
Kazakstan	18	174	--	--
Malaysia	10	154	--	--
Nigeria	40	1,510	19	699
Russia	--	--	79	872
Rwanda	31	598	71	1,260
South Africa	1	37	--	--
Spain	25	459	3	77
Sri Lanka	--	--	4	90
Thailand	127	988	60	997
Zaire	32	677	13	305
Total	1,020	23,400	1,130	26,400

1/ Data are rounded to three significant digits; may not add totals shown.
2/ Presumably country of transshipment rather than original source.
3/ Less than 1/2 unit.

Sources: Bureau of the Census and U.S. Geological Survey.

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TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Gwalia Consolidated Ltd. (Greenbushes)	Columbium-tantalum.
	Gwalia Consolidated Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM) (Araxa)	Columbium.
	Cia. de Estanho Minas Brasil (MIBRA) 1/	Columbium-tantalum.
	Paranapanema S.A. Mineracao Indústria e Construcao (Pitinga)	Columbium-tantalum.
	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior/Teck Corp. (Niobec)	Columbium.
	Tantalum Mining Corp. of Canada Ltd. (Tanco) 2/	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Gwalia Consolidated Ltd. (Greenbushes).	
Brazil	Cia. Industrial Fluminense. 1/	
	Mamoré Mineracao e Metalurgia. 3/	
Thailand	Thailand Smelting and Refining Co. Ltd. (Thaisarco).	
Production of columbium- and tantalum-bearing synthetic concentrates:		
Germany: Western states	Gesellschaft Für Elektrometallurgie mbH (GFE). 1/	
	H.C. Starck GmbH & Co. KG.	

1/ A wholly owned subsidiary of Metallurg Inc., New York, NY.
2/ A wholly owned subsidiary of Cabot Corp.
3/ A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country		Products 1/
Austria	Treibacher Chemische Werke AG	Nb and Ta oxide/carbide, FeNb, NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, NiNb.
	Cia. Industrial Fluminense 2/	Nb and Ta oxide.
	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Estonia	Silmet	Nb oxide/metal.
Germany: Western states	Gesellschaft Fur Elektrometallurgie mbH (GFE) 2/	FeNb, NiNb.
	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co.	Nb and Ta oxide/metal/carbide.
	Showa Cabot Supermetals 3/	Ta capacitor powder.
	H.C. Starck-V Tech Ltd. 4/	Ta capacitor powder.
Kazakstan	Ulba Metallurgical	Ta oxide/metal.
	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd. 4/	K-salt, Ta metal.
United States	Cabot Corp.	Nb and Ta oxide/metal, K-Salt, FeNb, NiNb, Ta capacitor powder.
	H.C. Starck Inc. 5/	Nb and Ta metal, Ta capacitor powder.
	Kennametal, Inc.	Nb and Ta carbide.
	Reading Alloys, Inc.	FeNb, NiNb.
	Shieldalloy Metallurgical Corp. 2/	FeNb, NiNb.
	Wah Chang 6/	Nb oxide/metal, FeNb, NiNb.
	H.C. Starck - TTI, Inc. 4/	Ta capacitor powder.

1/ Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
2/ A wholly owned subsidiary of Metallurg Inc., New York.
3/ A joint venture between Showa Denko and Cabot Corp.
4/ A subsidiary of H.C. Starck GmbH & Co. KG.
5/ Jointly owned by Bayer USA and H.C. Starck GmbH & Co. KG.
6/ A subsidiary of Allegheny Teledyne Inc.

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TABLE 10
COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country 5/	Gross weight 3/					Columbium content 4/					Tantalum content 4/				
	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996	1992	1993	1994	1995	1996
Australia: Columbite-tantalite	656	495	700	900	920	69	50	81	109	112	224	170	238	274	276
Brazil:															
Columbite-tantalite	200	175	175	175	190	45	40	40	40	45	60	50	50	50	55
Pyrochlore	29,600	22,700	30,700	36,900 r/	32,100	12,500	9,540	12,900	15,500 r/	13,500	--	--	--	--	--
Canada:															
Pyrochlore	5,100	5,320	5,130	5,230	5,160	2,300	2,390	2,310	2,350	2,320	--	--	--	--	--
Tantalite	200	100	144	130 r/	190	8	5	7	7 r/	10	48	25	36	33 r/	48
Namibia: Tantalite	-- r/	--	--	(6/)	--	-- r/	--	--	NA	--	-- r/	--	--	(6/)	--
Nigeria: Columbite	40	40	30	30	25	17	17	13	13	10	2	2	2	2	2
Rwanda: Columbite-tantalite	100	100	10	--	--	30	30	3	--	--	22	22	2	--	--
South Africa: Columbite-tantalite	(6/)	(6/)	--	--	--	(6/)	(6/)	--	--	--	(6/)	(6/)	--	--	--
Spain: Tantalite	8	6	6	-- r/	--	NA	NA	NA	-- r/	--	2	2	2	-- r/	--
Zaire:															
Columbite-tantalite	29	20	4	4	--	8	5	1	1	--	8	6	1	1	--
Pyrochlore	780	780	--	--	--	350	350	--	--	--	--	--	--	--	--
Zimbabwe: Columbite-tantalite	94	94	7	7	7	14	14	1	1	1	33	33	2	2	2
Total	36,800	29,800	36,900	43,400 r/	38,600	15,300	12,400	15,400	18,000 r/	16,000	399	310	333	362 r/	383

r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes columbium- and tantalum-bearing tin ores and slags. Production of tantalum contained in tin slags was, in thousand kilograms: 1992--160; 1993--132; 1994--NA; 1995--126; and 1996--82 according to data from the Tantalum-Niobium International Study Center. Table includes data available through July 10, 1997.

3/ Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentratres of columbite, tantalite, and pyrochlore where information is available to do so, and reported i groups such as columbite and tantalite where it is not.

4/ Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

5/ In addition to the countries listed, Bolivia, China, Russia, and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

6/ Less than 1/2 unit.

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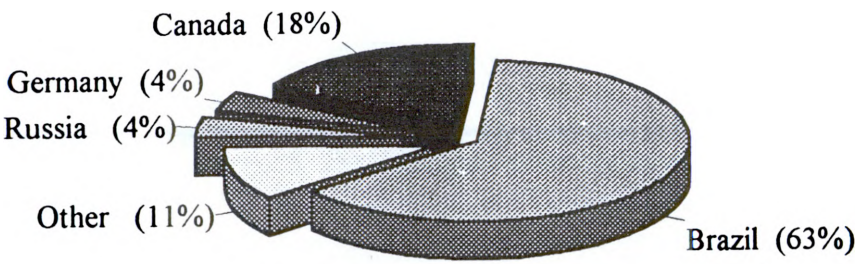
FIGURE 1
MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium Content)



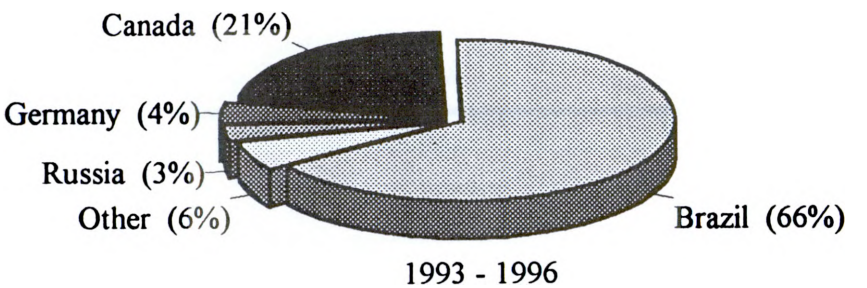
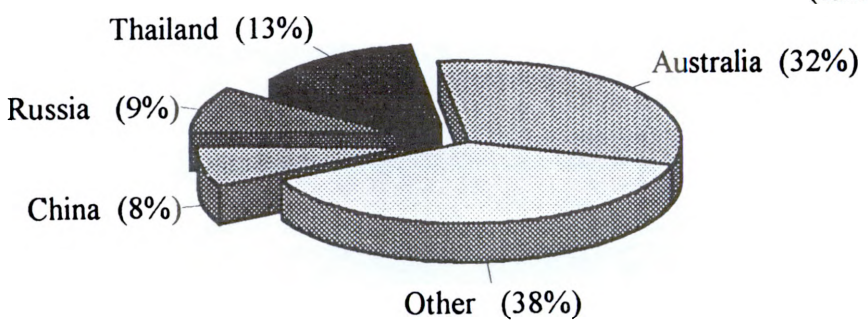
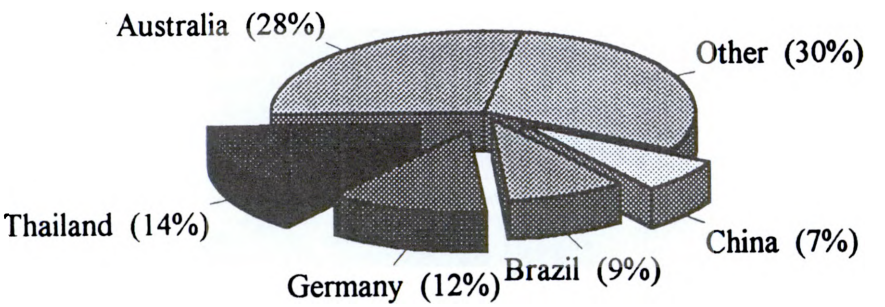


FIGURE 2
MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum Content)





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COPPER

By Daniel L. Edelstein

Mine production of recoverable copper in the United States continued its upward trend, rising by almost 4% to a record high level. A 20% decline in the average price received for refined copper, however, caused the estimated value of domestic mine production to decline by about 18%, to $4.6 billion. The United States maintained its position as the world's second largest mine producer of copper, accounting for about 18% of world production. Chile, where mine production increased 25%, was the largest mine producer, accounting for about 28% of world production.

Of the 37 mines operating in 10 States that produced reportable quantities of copper, the top 17 accounted for more than 98% of production. The principal mining States, in descending order, Arizona, Utah, New Mexico, Montana, Nevada, and Wisconsin, accounted for more than 99% of production. Mine capacity of 2.08 million metric tons was essentially unchanged from that of 1995. Capacity declines from the closure of one mine in Michigan and the depletion of ore reserves at several other mines were offset by the startup of one major new mine in Nevada and the incremental expansions of several mines in Arizona and New Mexico. Capacity utilization in 1996 rose to more than 92% as production rose at recently expanded mines. Capacity is expected to increase by about 50,000 metric tons in 1997.

During the year, 7 primary and 4 secondary smelters, 8 electrolytic and 6 fire refineries, and 13 electrowinning plants operated in the United States. Although capacity and capacity utilization changed, the operating status of these plants remained unchanged. The electrolytic refinery in Michigan, whose associated mine and smelter were closed in 1995, processed copper anode imported from Canada.

Electrowon production continued its upward trend, rising by about 6% from that of the previous year, and accounted for 30% and 25% of domestic mine production and refinery production, respectively. Conversion of old scrap to alloys and refined copper declined slightly, continuing a 4-year downward trend, but still contributed 428,000 tons of copper to the market, a quantity equivalent to about 16% of industrial copper consumption. Lower copper prices contributed to the decline in old scrap collection, accounting for the decline in copper recovered from scrap and the export of scrap materials.

Copper was consumed, as refined copper and as direct melt scrap, at about 35 brass mills, 15 wire-rod mills, and 600 foundries, chemical plants, and miscellaneous consumers. According to data compiled by the Copper Development Association Inc. (CDA), mill product shipments to the U.S. market, including net imports, rose to a record high level of 3.44 million tons. According to the CDA, copper and copper alloys found both structural and electrical uses in building construction (43%), electrical products (24%), industrial machinery and equipment (12%), transportation equipment (12%), and consumer and general products (9%) (Copper Development Association Inc., 1997).

The United States retained its position as the largest producer and consumer of refined copper, accounting for 19% and 21%, of world production and consumption, respectively. Domestic consumption of refined copper rose by about 3% in 1996, yet remained about 2% below the record-high consumption reported in 1994.

The net import reliance for refined copper, as a percentage of apparent consumption, rose to more than 13% from 6% in 1995. Canada was the largest U.S. trading partner for unwrought copper, accounting for 52% of refined copper imports, 47% of all imports of unwrought copper, and 42% of unwrought copper exports. Japan and Taiwan were the largest recipients of refined copper, together accounting for 51% of refined exports.

Copper was mined in about 50 countries, of which the top 2, Chile and the United States, accounted for 46% and the top 10, for about 83% of the world total. The world reserve base for copper was estimated to be 630 million tons, and world reserves, 320 million tons. The United States had about 15% each of reserves and reserve base.

Following a near balance between world production and consumption of refined copper in 1995, world inventories of refined copper resumed a downward trend. Combined inventories held on the London Metal Exchange (LME) and the New York Commodity Exchange (COMEX) declined by about 170,000 tons and were down 520,000 tons from 1993 peak levels. Though global copper prices remained, on average, high, mixed market signals, including near-term tightness in supply contrasted with forecasts of significant rises in mine production, led to high volatility in copper prices during the first 5 months of the year. Prices, however, plummeted in June following the revelation that a major international copper trading firm had sustained massive losses on unauthorized copper trades over a 10-year period. The U.S. producer price, which averaged $1.22 per pound during the first 5 months of the year, averaged only about $0.99 for the latter part of the year.

Legislation and Government Programs

The 1996 amendment to the Safe Drinking Water Act, which regulates the amount of lead that can be released into drinking water, was signed into law on August 6. It was well received by industry because it regulates the release of lead and not the

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absolute level of lead used in copper-base alloys used in plumbing fixtures and fittings. Under the new regulation, water used in prescribed leaching tests must acquire no more than 11 parts per billion lead from plumbing fixtures and fittings. Typical fixtures contain 2% to 3% lead; some cast products, however, contain up to 8% lead, the limit set in 1986. The new standard will allow engineering solutions, such as sealing of surfaces contacting water to prevent the leaching of exposed lead, to be applied to reduce lead levels in water and will not automatically require the use of low lead alloys (Platt's Metals Week, 1996c).

In October, the U.S. Environmental Protection Agency (EPA) denied a petition by the National Electrical Manufacturers Association to remove copper metal, other than fume or dust, from the list of toxic chemicals subject to the annual release reporting requirements of the Emergency Planning and Community Right-to-Know Act of 1986. Among other obligations, the act requires certain facilities manufacturing, or otherwise using listed toxic chemicals, including copper, to report their environmental releases of such chemicals on an annual basis. EPA also regulates copper metal smaller than 100 microns as a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act and has promulgated national primary drinking water regulations for copper ion in drinking water under the Safe Drinking Water Act (Environmental Protection Agency, 1996a).

In accordance with the Clean Air Act, EPA proposed new national ambient air quality standards for particulate matter and for ozone in December. The new particulate matter standard, which could have a significant impact on the mining and mineral-processing industries, was to provide increased protection against a wide range of particulate-matter-related health hazards. The new standard for particles that are 2.5 microns or smaller sets concentration limits of 15 micrograms per cubic meter as an annual mean and 50 micrograms per cubic meter as the 24-hour mean. The current standard regulates particles that are 10 microns in size or smaller and sets an average annual concentration limit of 50 micrograms per cubic meter and an average daily limit of 150 micrograms per cubic meter. A final copy of the proposed standard was expected in June 1997, with implementation anticipated in 2002 or 2003 (Environmental Protection Agency, 1996b).

In August, Congress enacted the extension of the Generalized System of Preferences (GSP) Program. The extension is retroactive to July 31, 1995, the previous expiration date of the program. The GSP Program grants duty-free status to certain imports from developing countries, subject to a threshold per capita gross national product and to specific import ceiling guidelines. Copper materials eligible for the GSP Program include copper ores and concentrates, unwrought copper, and certain copper semifabricates (Platt's Metals Week, 1996e).

In 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal came into force and has since been ratified by more than 100 countries, including the United States. Although the United States has not passed legislation necessary to implement the convention, the domestic scrap industry feels that the Basel Convention's imprecise definition of hazardous wastes threatens to place obstacles in the path of trade in recyclable materials, including copper scrap. In the Third Conference of the Parties to the Basel Convention held in September 1995, a proposal was adopted that would ban exports of hazardous waste from countries belonging to the Organization for Economic Cooperation and Development (OECD), which includes the United States, to non-OECD countries. Exports of scrap from the United States to non-OECD countries could be adversely affected. An international Technical Working Group met four times between September 1995 and February 1997 to consider which materials should be classified as hazardous and, hence, affected by the various bans. As of February 1997, copper scrap, copper slags, and copper oxide mill scale had been included in the B list, the list of materials not covered by the Basel Convention as hazardous and, thus, not subject to any export ban (Buchholtz, 1997).

Production

Following a break in 1995 in the 10-year upward trend in mine production, mine production in 1996 rose about 4% to a record high level owing to the opening of one major new mine, the Robinson Mine in Nevada, and incremental expansions at several others, including the Mission and Ray Mines in Arizona, and the Continental Mine in New Mexico. Partially offsetting these increases in production, however, were decreases from the closures of the White Pine Mine in Michigan and the Pinos Altos Mine in New Mexico and the depletion of open-pit oxide reserves at the San Manuel Mine in Arizona in 1995, and closure of the Superior and Oracle Ridge Mines in Arizona in 1996.

Capacity utilization at domestic mines averaged about 92% in 1996, an increase from the past 2 years when the utilization rate averaged 90%. The increase was attributed to the 1995 closure of several mines that had operated significantly below capacity and the attainment of full production potential at mines that had undergone incremental capacity expansions in 1995. Capacity utilization rates, on average, have trended upward since 1982, when contraction in the domestic copper industry lowered the mine utilization rate to 61%. As a result of the higher capacity utilization rates and the closure of several labor-intensive underground mines in 1995 and 1996, productivity at domestic mines in 1996, as calculated from employment data compiled by the Mine Health and Safety Administration, rose to a record-high 68 kilograms of copper per worker-hour, compared with 64 kilograms in 1995; productivity has generally trended upward since 1989, when only 50 kilograms of copper per worker-hour was produced.

Although domestic smelter production rose slightly from the 1995 depressed level, it remained well below the 1994 level owing to closure of Southwire Co.'s Gaston, SC, secondary smelter in 1994 and White Pine's primary smelter in 1995. With the exception of Kennecott's new smelter in Utah, which

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continued to experience startup difficulties, domestic copper producers reported record-high primary smelter output. Primary refined production rose by almost 5% to a record high level owing to increased electrowon production and increased production from imported anode. Capacity utilization at domestic smelters and refineries was estimated to be 88% and 87%, respectively.

Company Reviews.—ASARCO Incorporated's copper mine production, including its share of Southern Peru Copper Corp.'s (SPCC) production, rose 13% to more than 460,000 tons, making it the fourth largest private sector copper producer in the world. Production at its Mission Mine in Arizona increased by 16% to 118,000 tons owing to higher ore grades afforded by underground operations. Developmental drilling expanded proven reserves by 7% to 485 million tons of ore, and construction began on a conveyor to haul an estimated 53 million tons of waste per year from stripping operations at the pit beginning in early 1997. Production at the Ray Mine rose to 248,000 tons, an increase of about 12,000 tons, following an 11-month accelerated stripping program that provided access to high-grade ore. Production would have been higher had it not been reduced during the fourth quarter to lower concentrate inventory and to accelerate removal of overburden. At the Hayden smelter, production rose by 11% to a record 390,000 tons owing to improved equipment reliability. Production at the El Paso CONTOP furnace declined by about 9% to 104,000 tons. The acid plant was refurbished and additional equipment upgrades were planned for 1997 to improve smelter reliability. In January, construction began on a solvent extraction-electrowinning (SX-EW) plant at the Silver Bell Mine. The project was projected to produce 16,000 tons of refined copper per year when completed in mid-1997. Mitsui & Co. Ltd. of Japan held a 25% interest in the project (ASARCO Incorporated, 1997).

At yearend, Arimetco International Inc., owner and operator of the Yerington Mine in Nevada and the Johnson Camp Mine in Arizona, announced that it had filed for reorganization under Chapter 11 of the U.S. Federal Bankruptcy Code. The company cited as the source of its financial difficulties the compound impact of lower copper prices, serious production problems at its Yerington Mine that temporarily lowered output and raised unit production costs, and the high cost of maintaining and developing nonproducing properties (Platt's Metals Week, 1997a). Arimetco had reported a net loss for the third quarter of 1996 and a year-to-date modest net income of $163,000 compared with a 9-month profit of $5.8 million in 1995. The company reported that the installation of a three-stage crushing unit to expand SX-EW capacity at Yerington to 65,000 pounds per day had been completed; a similar system had been installed at its Johnson Camp Mine in 1995 to boost production to 35,000 pounds per day. Arimetco also reported completing the purchase of the Sullivan ore body and the adjacent fully-permitted Paradise Peak processing plant near Gabbs, NV, from FMC Gold Corp. The company anticipated that environmental permits would be approved, and production would begin in late 1997 (Arimetco International Inc., 1996).

In January, Broken Hill Proprietary Co. Ltd. (BHP) of Australia acquired 87% of Magma Copper Co.'s voting shares to become the third multinational corporation after RTZ-CRA Group (Kennecott) and Inmet Mining Corp. (Copper Range) to acquire the assets of a major U.S. copper producer. With the purchase of Magma, BHP became the world's second largest producer of copper, with production in excess of 800,000 tons of copper per year, and formed a new operating entity, BHP Copper Group, headquartered in San Francisco. BHP already owned 57.5% of the Escondida Mine in Chile, the world's largest copper project in terms of annual mine output (Graham and Allum, 1995).

In June, BHP Copper closed its underground Superior Mine in Arizona because of depletion of ore in the C-Bed ore body. Ore grade had been a rich 5.5% copper with significant gold and silver values (Carter, 1996). The mine was placed on care and maintenance pending discovery of an additional ore body, although the company temporarily suspended its underground and surface exploration drilling programs. When fully operational, the mine capacity was about 20,000 tons per year of copper in concentrate (Southwestern Pay Dirt, 1996b). In February, BHP reported its first production from its Robinson Mine at the former Liberty Pit, last operated by Kennecott (Southwestern Pay Dirt, 1996a). The Robinson Property encompasses three principal mining areas—the Liberty, the Veteran-Trip, and the Ruth Pits—that BHP intends to mine sequentially. By yearend, Robinson was operating at its rated capacity of 70,000 tons of copper per year in concentrate. At the company's San Manuel Mine, the Lower Kalamazoo ore body was accessed; a tunnel boring machine was used to excavate a 9.5- kilometer tunnel. The Kalamazoo ore was expected to extend mine life until 2001 (Carter, 1996). Development of the ore body progressed throughout the year, and production began during the fourth quarter. Underground production capacity is projected to rise to 118,000 tons per year of copper in concentrate in 1997 from the current 100,000 tons per year. Production of electrowon copper at San Manuel continued to decline following depletion of open-pit oxide reserves. Production from in situ leaching was projected to stabilize at about 23,000 tons of cathode per year.

Cobre Mining Company, Inc., which operates the two underground mines and one open pit that constitute the Continental Mine in New Mexico, reported production increases of 30% in each of the past 2 years and produced a record 32,000 tons of copper in concentrate in 1996. At yearend, Cobre, which employed contract miners, was looking to reduce costs through the purchase of its own mining fleet, and was seeking permit approval and outside financing for the construction of a 20,000-ton-per-year SX-EW plant (Cobre Mining Company, Inc., 1997).

According to the Cyprus Amax Minerals Company annual report, total company copper production rose by about 12% to a record 348,000 tons, and cash operating costs declined by $0.05 per pound owing to improvements to domestic operations and to additional lower cost Chilean production. In December 1996, commercial production of electrowon copper cathode

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began at the El Abra project in Chile. In June 1994, Cyprus Amax acquired a 51% interest in the project from Corporacion Nacional de Chile at a cost of $330 million, and construction began in February 1995.

At Cyprus Amax's Bagdad Mine in Arizona, production rose by 7% to about 100,000 tons owing to a 10% increase in concentrate production. Electrowon production of 12,000 tons was down from 14,000 tons in 1995. At the adjacent Sierrita and Twin Buttes Mines, production declined about 4% to 105,000 tons owing to reduced concentrate production. Electrowon production from oxide and low-grade sulfide dumps at the two mines rose to 16,000 tons, increasing by about 2,700 tons. Sulfide reserves at Twin Buttes were exhausted in 1994. At its Miami, AZ, operations, SX-EW production rose by 12% to 65,000 tons, and the smelter processed a record-high 574,000 tons of concentrate, allowing the new electrolytic refinery to increase production by 20% to 156,000 tons. At the Tohono operations in Casa Grande, AZ, SX-EW production rose by 15% to almost 18,000 tons. At yearend 1996, however, Cyprus suspended mining operations at its test open pit while it further evaluated mining options for large-scale production at Tohono. Production was expected to continue from existing tailings, leach pads, and in situ ore (Cyprus Amax Minerals Co., 1997).

Oracle Ridge Mining Partners, 70% owned by Santa Catalina Mining Corp. (formerly South Atlantic Ventures, Ltd.) and 30% owned by Continental Materials, suspended production at the Oracle Ridge Mine in Arizona in midyear and was reported to be interested in selling the mine. According to the Arizona Department of Mines and Resources, Oracle Ridge produced about 4,400 tons of copper in concentrate in 1995 (Phillips, 1997).

At Phelps Dodge Corp.'s domestic mines, production, including minority participants' share, rose by almost 12% to a record-high 690,000 tons, 54% of which was from SX-EW production. At the Morenci Complex, which consists of an open pit, two concentrators, three solvent extraction facilities, and two electrowinning tankhouses, production of both concentrate and SX-EW cathode rose to record-high levels. Recoverable copper in concentrate increased by 17% owing to increased grinding capacity, improvements in the process control system, and a rise in mill-head grade from 0.64% to 0.70%. SX-EW production rose by 16% to 238,000 tons owing to a full year's operation of the Southside Extension project, completed during the third quarter of 1995. At the Chino Mine, production of 90,000 tons of copper in concentrate remained essentially unchanged, as higher mill throughput compensated for lower ore grades. Electrowon production of 63,000 tons also was unchanged. During the year, the Chino Mine operators began to integrate a variety of artificial intelligence concepts to better manage the varied ore found within the pit. SX-EW production at the Tyrone Mine rose by almost 9% to a record high 69,000 tons (Phelps Dodge Corp., 1997a).

During the year, Phelps Dodge maintained an active domestic exploration program. At Tyrone, an additional 300 million tons of leachable reserves grading 0.32% copper was identified. A feasibility study and the environmental permitting process were initiated for the development of the Dos Pobres deposit, where more than 550 million tons of leach and sulfide ore had thus far been identified. A resource and feasibility study was completed at the Ajo Property, where operations had been discontinued in 1985 (Phelps Dodge Corp., 1997a). In April 1997, Phelps Dodge announced that it planned to invest $238 million to construct a new 38,000-ton-of-ore-per-day concentrator, to purchase mining equipment, and to improve the infrastructure at Ajo. Construction was projected to begin in early 1998 and startup was scheduled for late 1999 (Phelps Dodge Corp., 1997b).

According to the RTZ-CRA annual report, production at the Bingham Canyon Mine in Utah declined by 3% to 297,000 tons as lower ore grades were partially offset by higher mill throughput. Refined production, however, fell by 24% from its already low level owing to continued production shortfalls from its new smelter. The new smelter, billed as the environmentally cleanest in the world, had performance difficulties with the anode furnace and casting facilities. The company announced plans to close the smelter for 6 weeks during the second quarter of 1997 to replace refractories and furnace cooling blocks and to rebuild anode- casting facilities. Production at the Flambeau Mine in Wisconsin rose by 6% to 41,500 tons. Flambeau reserves will be exhausted in 1997, and mine reclamation is scheduled to begin by midyear (RTZ-CRA, 1997).

Trade

In response to increased demand, net imports of refined copper rose to 374,000 tons, compared with 211,000 tons in 1995. With the exception of the category containing matte, ash, and residues, all exports of unmanufactured copper products declined in 1996. Combined with increases in imports of both refined copper and anode copper, this resulted in the United States switching from being a net exporter of unwrought copper products in 1995, to a net importer in 1996. Exports of copper ore and concentrate to Canada declined by 46,000 tons following the closure of the White Pine Mine in September 1995 and lower shipments from the Flambeau Mine in Wisconsin. White Pine had been exporting concentrate to Canada since early 1995 when its captive smelter was closed. Following closure of the White Pine smelter, imports of blister and anode from Canada increased in 1995 and 1996. The White Pine refinery continued to operate on imported anode. Increased substitution of imported blister and anode at refineries that traditionally processed secondary anode also contributed to the rise in blister/anode imports. Exports of copper and copper-alloy scrap declined in 1996 owing to lower scrap availability and lower foreign demand.

According to Bureau of the Census data compiled by the Copper and Brass Fabricators Council, U.S. net imports of all copper and copper-alloy semifabricated products (63,000 tons) were down about 30% from those of the previous year. Canada and Mexico, the largest U.S. trading partners, together accounted for 59% of semifabricated copper exports and 34% of imports. An increase in net imports from Canada of about

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14,000 tons was essentially balanced by a decline in net imports from Mexico. Imports and exports of semifabricates to Mexico of about 45,000 tons were essentially balanced in 1996 (Copper and Brass Fabricators Council, Inc., 1997).

Prices and Stocks

According to data compiled by the International Copper Study Group (ICSG), global inventories of refined copper declined by almost 200,000 tons, or 24%, in 1996. Most of the decline occurred at LME warehouses, where inventories declined by 177,000 tons (International Copper Study Group, 1997). In the United States, inventories fell by 17,000 tons as increases in consumer and COMEX inventories were more than offset by a decline in LME stocks held in U.S. warehouses.

While yearend inventories were down by about 200,000 tons, inventories at the end of May were down only about 27,000 tons from yearend 1995. During this period, the average U.S. monthly producer price was reasonably stable, ranging from a low of $1.20 per pound in February to a high of $1.27 in May. Daily prices during this period, however, exhibited extreme volatility. In January, the U.S. producer price ranged from a high of $1.28 cents per pound to a low of $1.16 per pound. In May, the U.S. producer price rose to more than $1.33 per pound after news of a strike at the Chuquicamata Mine in Chile and other possible supply disruptions but fell back to under $1.20 per pound 1 week later after resolution of the strike. The price volatility was underlain by a tight balance between supply and demand and uncertain market fundamentals. While most analysts were predicting a large growth in mine production during the year, signals concerning refined copper supply were mixed. Spot treatment and refining charges were reported to be at high levels, indicating a possible smelter bottleneck, and tight supplies in the United States relative to Europe led to Comex trading at a $0.05-per-pound premium to LME prices in February.

In June, copper prices plummeted following revelations that Sumitomo Corp., a major global copper trader, had sustained losses in excess of $1.8 billion on unauthorized copper trades during a 10-year period (Platt's Metals Week, 1996g). By the second week in July, the U.S. producer price declined to $0.92 per pound, the lowest level in more than 2 years. Despite company denials, rumors that Sumitomo held large unreported inventories of copper continued to have a dampening effect on prices. In September, the company revised its estimated losses upward to $2.6 billion (Platt's Metals Week, 1996h). The Sumitomo losses sparked a continuing controversy over the clearing practices of the LME and its oversight by regulators. By yearend, LME practices in conjunction with the Sumitomo losses were under investigation by the Commodities Futures Trading Commission and Congress in the United States and by the Securities and Investments Board in the United Kingdom (Platt's Metals Week, 1996i). Congress was investigating the possibility of amending the U.S. Commodity Exchange Act to allow for regulation of foreign futures contracts that are deliverable in the United States; this was directed at the LME warehouses that had opened in the United States during 1995 (Platt's Metals Week, 1996d).

With stabilization of copper prices at a lower level following the Sumitomo revelations, the U.S. producer price averaged $0.95 per pound between July and October. World inventories rose slightly in August and September, further serving to hold down prices. Inventories, however, declined sharply in October, and by November, in response to tight global supplies, price volatility returned to the market, though prices, on average, trended upward. The U.S. producer price averaged $1.04 per pound for both November and December.

Consumption

Consumption of refined copper by domestic manufacturers rose by more than 3% in 1996, to 2.62 million tons, yet remained below the record level established in 1994. In addition to refined copper, domestic manufacturers directly consumed (melted or processed into chemicals) 1.13 million tons of copper-base scrap containing about 885,000 tons of recoverable copper. An additional 70,000 tons of copper was recovered in the consumption of aluminum-, nickel-, and zinc-base scrap. The total quantity of copper recoverable from the direct consumption of scrap, 956,000 tons, was unchanged from that of the previous year.

Consumption of refined copper at wire-rod mills increased by about 2% and accounted for about 76% of domestic consumption of refined copper despite the closure of two wire-rod mills in September, 1995—one, owned by Southwire, in Gaston, SC, and the other, owned by Westinghouse Electric Co., in Abingdon, VA; the mills had a combined annual capacity of about 225,000 tons of rod. In response to these closures, several mills took steps to increase capacity. According to its company annual report, Asarco completed an upgrade to its wire-rod mill at Amarillo that increased capacity by 17% (ASARCO Incorporated, 1997). Cyprus Amax Minerals Co. reported that its Miami, AZ, wire-rod mill operated above design capacity in 1996, producing 125,000 tons of rod, and that its total rod sales increased to 213,000 from 206,000 tons in 1995 (Cyprus Amax Minerals Company, 1997). Phelps Dodge, the world's largest producer of copper wire rod, boosted the combined wire-rod capacity and production at its El Paso, TX, and Norwich, CT, plants by 50,000 tons, to 635,000 and 645,000 tons, respectively (Phelps Dodge Corp., 1997a).

Brass mills were the second largest consumers of refined copper and largest consumers of copper base scrap, accounting for 22% of refined consumption and about 55% of scrap consumption. Consumption of refined copper at brass mills rose by 10%, while copper recovered from scrap consumed at brass mills was essentially unchanged. The increase in refined copper consumption, as a percentage of total consumption of materials at brass mills, reflected reduced scrap availability. The tightness in the scrap market was attributed to several factors, including lower copper prices and less scrap generation from more-efficient manufacturing.

According to data compiled by the CDA, shipments of

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copper and copper-alloy products to the U.S. market by fabricators (wire mills, brass mills, foundries, and powder producers), including net imports, rose by about 3% to a record-high 3.4 million tons containing an estimated 3.1 million tons of copper. About 70% of these shipments were as pure (unalloyed) copper products. Wire mill products accounted for about 45% of total shipments to the domestic market. In building construction, the largest end use, shipments rose by almost 8% and accounted for about 43% of the market. Building construction included products used for building wire, plumbing and heating, air conditioning and commercial refrigeration, builders hardware, and architectural applications. Other uses included: electric and electrical products, 24% of shipments; industrial machinery and transportation equipment, each 12%; and consumer and general products, 9% (Copper Development Association, 1997).

World Review

World production and consumption of refined copper were in near balance in 1996 for the second consecutive year. Depending on whether stock changes or the balance between apparent consumption and production is used as the measurement of refined copper availability, the world either experienced a slight deficit or slight surplus in refined copper production relative to demand. According to data compiled by the ICSG, world inventories of refined copper declined by about 200,000 tons, although calculation of the world supply balance, production minus consumption, indicated a slight surplus of 100,000 tons. Compared with a demand of 12.5 million tons, however, the surplus or deficit was relatively small, and the world copper market was marked by tightness in spot supplies and volatility in prices (International Copper Study Group, 1997a).

According to ICSG data, world demand for refined copper rose by about 440,000 tons, an increase of 3.6%, despite stagnant demand in Western Europe. In addition to that in the United States, demand growth was significant in Turkey, 16%; the newly industrialized Asian countries of Indonesia, Malaysia, the Republic of Korea and Thailand, 13%; China, 10%; and Japan, 4.6% (International Copper Study Group, 1997a). Growth in Turkey and the newly industrialized coun-tries corresponds to recent increases in semfabricate capacity.

World mine production rose by a record 890,000 tons, 9%, to almost 11 million tons. Large production increases in Australia, Chile, Indonesia, and Peru, whose combined production of copper rose by more than 900,000 tons, were partially offset by declines in several countries, including Canada, the Philippines, and Russia. According to data compiled by the ICSG, the world mine capacity utilization rate has trended upward for at least the past 5 years, rising above 90% in 1996 (International Copper Study Group, 1997a).

World smelter production rose by about 380,000 tons in 1996, to 10.6 million tons. The increase was accounted for by increased primary production; the quantity of copper recovered from scrap was unchanged from that of 1995. Estimated world smelter capacity rose by only about 250,000 tons. Although improved, the average capacity utilization rate at smelters remained low at about 81%, compared with about 80% in 1995. Although numerous smelter projects were planned and capacity was forecast to rise by almost 1.4 million tons during the next 2 years, only a handful of major expansions took place in 1996. In Spain, Atlantic Copper Holdings, S.A., formerly Rio Tinto Minera S.A., completed expansion of its smelter/refinery, doubling capacity to 270,000 tons of copper per year. Further smelter modifications were underway that were expected to raise capacity by an additional 20,000 tons per year in 1997 (Freeport-McMoRan Copper and Gold Inc., 1997). In China, Daye Nonferrous Metals Company commissioned a new Noranda smelter late in 1995 that was expected to produce as much as 100,000 tons of copper at capacity. At Finland's Harjavalta smelter, a converter modernization completed in 1995 helped boost 1996 capacity by 60,000 tons.

World production of refined copper rose substantially for the second straight year, increasing by 650,000 tons, or 5%. More than 50% of the increased refined production (360,000 tons) was from expansion of electrowon production, especially in Chile, Peru, and the United States, where SX-EW production rose by 263,000, 55,000, and 34,000 tons, respectively. Chile, with electrowon production of 636,000 tons, surpassed the United States as the largest producer of SX-EW copper.

Argentina.—Development was proceeding on the Bajo el Alumbrera Mine, owned by MIM Holdings Ltd. (50%), North Ltd. (25%), and Rio Algol (25%). The project, with proven and probable ore reserves of almost 700 million tons, is expected to cost almost $1 billion to develop and is projected to come on-stream in 1997. Capacity is projected to rise to 190,000 tons of copper per year by 1999 (Mining Magazine, 1997). A second property nearby, Agua Rica, 70% owned by BHP, was reported to have 1.2 billion tons of copper resources; development has not been announced (Platt's Metals Week, 1996b).

Australia.—Mine production increased owing to production at several mines that started up during 1995, including Placer Pacific Ltd.'s Osborne Mine, with a projected capacity of 36,000 tons per year, and North Broken Hill Ltd.'s Goonumbla Mine, with a projected annual capacity of 72,000 tons by 1998 (International Copper Study Group, 1997a).

Canada.— Although production and capacity declined in 1996, several projects were under development in Canada that are expected to significantly increase capacity by 1999. In British Columbia, Princeton Mining Co. suspended operations in November at its Similco Mine because of lower copper prices. In August, Inco completed its acquisition of Diamond Fields Resources, Inc., giving it a controlling interest in the Voisey's Bay nickel-copper-cobalt project, which contains an estimated 150 million tons of ore reserves. Voisey's Bay is expected to produce as much as 90,000 tons of copper in concentrate per year beginning in mid-1999. Royal Oak Mines Inc. began construction in July at its Kemess project in British Columbia. Production of 26,000 tons per year of copper in concentrate was expected to begin in 1998. Princeton Mining announced that it had received British Columbia Government

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approval to develop its Huckleberry copper-molybdenum mine, which was projected to produce 29,500 tons of contained copper per year beginning in late 1997 (Bokovay, 1997). In April, Asarco announced its intended development of the Minto copper-gold-silver mine in the Yukon Territory. Asarco obtained an 84% interest in the project from Minto Explorations Ltd. earlier in the year. Production of 12,000 tons per year of copper in concentrate was scheduled to begin in 1998 (ASARCO Incorporated, 1997).

Chile.—Mine production and capacity continued to soar, both rising by about 600,000 tons. The Escondida Mine became the world's largest copper mine following the completion of a $560 million Phase 3 expansion that raised production capacity from 480,000 to more than 800,000 tons per year. Production in 1996 rose to 853,000 tons of copper in concentrate. Permit applications were submitted for a $470 million oxide ore SX-EW project to produce 125,000 tons per year of refined copper. If approved, production could begin in late 1998 (RTZ-CRA, 1997).

Cyprus Amax Minerals completed construction of its El Abra project ahead of schedule and reported its first commercial production of almost 19,000 tons of cathode in December. Projections called for an annualized production of 225,000 tons by the end of the first quarter of 1997. With identified leach reserves of 800 million tons, El Abra was expected to have a mine life of at least 17 years (Cyprus Amax Minerals Company, 1997).

In 1996, production at the Candelaria Mine, owned by Phelps Dodge (80%), declined to about 137,000 tons of copper in concentrate owing to lower ore grades. The mine, which began production in 1994, had reached full capacity of 150,000 tons in 1995. In May, Phelps Dodge announced a $337 million concentrator expansion project that will increase capacity to about 200,000 tons of copper in concentrate and reduce projected mine life from 35 years to 19 years (Phelps Dodge Corp., 1997a).

The Andacollo Mine, a majority share of which was sold by the state-owned Empresa Nacional de Mineria (ENAMI) to Canada Tungsten (63%) and Compania Minera del Pacifico (27%), began production late in 1996. At capacity, Andacolla is expected to produce 20,000 tons per year of SX-EW cathode (Platt's Metals Week, 1996a).

Despite a 10-day strike, production rose to 631,000 tons, an increase of about 10,000 tons, at the Chuquicamata Division of state-owned Codelco (Platt's Metals Week, 1997b). At the El Teniente Division, production was resumed at the sublevel 6 area of the mine. Production from that section had been abandoned in 1991 after numerous rock bursts. At the Andina Division, Codelco reported plans for a $200 million expansion that would increase capacity to 250,000 tons per year, an increase of 100,000 tons. Codelco also began construction of the Redeemer Tomic open pit leach/SX-EW project. Initial output at a rate of 150,000 tons of cathode per year was expected to start up by January 1998 (CRU Copper Monitor, 1996).

Indonesia.—Continued expansion of Freeport-McMoRan Copper and Gold Inc.'s Grasberg Mine in Irian Jaya raised production by 14% to 507,000 tons of recoverable copper. In 1996, an average of 127,000 tons of ore per day having an average grade of 1.35% copper was processed through Grasberg's two crushing stations and three concentrators. Feasibility studies were completed, and construction begun on a fourth concentrator that will boost ore processing to between 190,000 and 200,000 tons per day. At yearend, proven and probable reserves at Grasberg reportedly amounted to 2 billion tons of ore grading 1.19% copper (Freeport-McMoRan Copper and Gold Inc., 1997).

Peru.—Production from SPCC operations rose by 22% to a record high 308,000 tons. In April, Asarco announced the discovery of new reserves at SPCC's Cuajone and Toquepala Mines that boosted SPCC's yearend 1995 reserves to almost 1.8 billion tons (1.2 billion tons of sulfide ore and 6 million tons of oxide ore) (Platt's Metals Week, 1996f); yearend 1994 reserves had been listed at only 500 million tons. By yearend 1996, total SPCC reserves had been expanded to 2.2 billion tons owing to development drilling that further increased reserves at Cuajone by 44%. As a result of the large reserve potential at Cuajone, engineering work was underway at yearend 1996 to expand milling capacity by 50% and production by 118,000 tons per year. Downstream at SPCC's Ilo smelter, the new El Teniente converter and acid plant, which started up in October 1995, was operating successfully, and expansion of the acid plant was begun to increase sulfur dioxide capture from 18% to 30% by 1998. Capacity at the Ilo electrolytic refinery was increased by 20% in 1996 to 224,000 tons per year (ASARCO Incorporated, 1996).

Zambia.—Following 4 years of studies, the state-owned Zambia Consolidated Copper Mines Ltd. (ZCCM) proceeded with plans to privatize copper operations. In January, it reached an agreement with South Africa's Anglo American Corp. by which Anglo would lead a syndicate of investors to fund the estimated $600 million needed to develop the Konkola Deep project. At yearend, ZCCM was offering at least nine different packages to a group of prequalified investors for distribution of ZCCM's mining and electrical power assets (Mining Annual Review, 1997).

Current Research and Technology

Asarco and Freeport-McMoRan Copper & Gold are joint venture partners in the Santa Cruz In situ Research Project in Casa Grande, AZ, which is managed by Asarco, and 75% funded by the Federal Government. Based on earlier research conducted by the former U.S. Bureau of Mines, the project objective is to recover copper from deep mineralized zones through surface injection of an acid solvent and recovery of pregnant leach solutions. The joint venture owns a deep mineralized ore deposit estimated to contain 1 billion tons of acid-soluble ore grading 0.55% copper. The grade of the ore body is too low for economic recovery of copper using underground mining methods and too deep for open-pit extraction. A pilot-scale SX-EW plant was completed in 1995,

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copper-bearing leach solutions were recovered following surface injection in 1996, and electrowon copper was recovered at the pilot plant in early 1997. Asarco reported that the commercial viability of the project had yet to be determined (ASARCO Incorporated, 1997). Meanwhile, Inmet Mining suspended pilot-scale solution mining from its closed White Pine Mine pending the outcome of permit applications for a full-scale plant.

Southwire, a leading domestic cable manufacturer, as well as a secondary smelter and refiner of copper, is developing a commercial superconducting power transmission cable that could replace conventional cables in congested urban underground distribution networks, delivering three to five times as much power as a similarly sized conventional copper conductor. At yearend Southwire and the U.S. Department of Energy had completed an 18-month joint test program of 1-meter lengths of prototype superconducting cable using copper oxide-based powder conductors. Southwire hoped to have a commercial cable available in 5 to 7 years (Metal Bulletin Monthly, 1997).

During the past several years, a broad-based group of companies, headed by the American Foundrymen's Society, Inc., with financial support from the U.S. Department of Commerce and industry trade groups, has been working to develop alternatives to the leaded red brasses used in casting alloys. In part, these efforts are in response to EPA drinking water regulations which lower the maximum permissible lead levels in drinking water and to Occupational Safety and Health Administration regulations of lead emissions at nonferrous foundries. A new series of bismuth/selenium modified alloys were developed, trademarked as Se-Biloy, that exhibit many of the same casting and machining properties of the leaded brasses they are intended to replace (Peters, 1997).

Outlook

U.S. mine production is expected to increase in 1997 by about 50,000 tons owing to incremental expansions at the Continental, the Mission, the Robinson, the San Manuel, and the Silver Bell Mines. Only one small heap-leach operation at Centurion Mines Corp.'s OK Mine is scheduled for startup, and one mine, the Flambeau Mine, was scheduled to close by mid-1997 because of ore depletion. Domestic capacity is projected to grow an additional 60,000 tons in 1998 with the startup of several new SX-EW projects.

Refinery production is expected to increase by about 75,000 tons with the startup of electrowinning at Asarco's Silver Bell Mine and the completion of anode casting modifications at the Kennecott smelter in Utah. In the first half of 1997, Kennecott's new smelter, and associated refinery, operated well below capacity, as they had since the smelter was installed in 1995. Domestic refined production in 1998 could rise by an additonal 100,000 tons, assuming full-year, full-capacity production at Kennecott.

Consumption of refined copper during the first 6 months of 1997 was about 4% higher than in the equivalent period in 1996; consumption for the full year 1997 is projected to rise only about 3% above that of 1996. Increased domestic production, coupled with increased net imports, is expected to be adequate to meet the increased demand. The amount of copper recovered from old scrap, which has trended downward over the past several years, increased during the first half of 1997 in response to higher average copper prices but, in the longterm, is expected to remain near that of 1996. No new secondary capacity is expected, and lower prices could further depress scrap collection. Recycling of new scrap has trended upward with increased domestic consumption of mill products. Its future growth is expected to lag behind that of copper demand growth owing to improvements in manufacturing processes that reduce scrap generation.

World mine capacity is expected to grow rapidly in the next several years. According to data compiled by the ICSG, world mine capacity can be expected to grow by about 500,000 tons in 1997. Smelter and refinery capacity are projected to at least keep pace, or outstrip the growth in mine production (International Copper Study Group, 1997b). Assuming a 3% growth rate, world consumption is expected to grow by about 400,000 tons.

Beyond 1997, growth of mine capacity is expected to accelerate and outstrip that of consumption. Annual capacity at operating mines or mines now under development is projected to rise from the current 12 million tons to 15 million tons by 2000. About 1.1 million tons of the increase is projected to come from SX-EW production. Chile is expected to account for most of the increase, where capacity is expected to grow from the current 3.1 million tons to as much as 4.9 million tons per year. Significant increases are also projected for Argentina, Australia, Canada, Indonesia, Peru, and Zambia. This growth has been stimulated by changes in the global investment climate. Such countries as Chile, Peru, and Argentina have changed mining laws to encourage foreign investment. In 1996, Zambia finally committed to privatization of the state-controlled mining industry, which may reverse its downward production trend.

With new smelter projects under consideration in more than a dozen countries, smelter capacity could rise by more than 2 million tons by 2000, thus keeping pace with the projected growth in copper contained in concentrates.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT COPPER STATISTICS 1/

(Metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Mine production:						
Ore concentrated 2/	thousand metric tons	263,000	262,000	271,000	267,000	274,000
Average yield of copper 2/	percent	0.48	0.49	0.47	0.46 r/	0.46
Recoverable copper:						
Arizona		1,150,000	1,160,000	1,160,000	1,170,000	1,240,000
Michigan, Montana, Utah		385,000	387,000	397,000	384,000	339,000
New Mexico		211,000	224,000	234,000	250,000	256,000
Other States		16,000	31,100	55,700	47,400	84,700
Total recoverable		1,760,000	1,800,000	1,850,000	1,850,000	1,920,000
Total value	millions	$4,180	$3,640	$4,430	$5,640	$4,610
Smelter production: 3/						
From domestic and foreign ores		1,180,000	1,270,000	1,310,000	1,250,000 r/	1,300,000
From scrap (new and old)		394,000	415,000	397,000	354,000 r/	339,000
Total smelter		1,570,000	1,680,000	1,710,000	1,600,000	1,640,000
Byproduct sulfuric acid	thousand metric tons	1,090	1,230	1,200	1,210	1,430
Refinery production:						
Primary materials:						
Electrolytic from domestic ores		1,110,000	1,210,000	1,280,000	1,300,000 r/	1,290,000
Electrolytic from foreign materials		96,100	88,600	63,500	91,200 r/	147,000
Electrowon		502,000	491,000	493,000	539,000	574,000
Total primary		1,710,000	1,790,000	1,840,000	1,930,000	2,010,000
Secondary materials (scrap):						
Electrolytic		331,000	337,000	269,000	215,000	193,000
Fire refined		102,000	123,000	122,000	137,000	140,000
Total secondary		433,000	460,000	392,000	352,000	333,000
Total refined		2,140,000	2,250,000	2,230,000	2,280,000	2,340,000
Secondary copper produced:						
Recovered from new scrap		723,000	748,000	827,000	874,000	872,000
Recovered from old scrap		555,000	543,000	500,000	442,000	428,000
Total copper from scrap		1,280,000	1,290,000	1,330,000	1,320,000	1,300,000
Copper sulfate:						
Production		46,800	46,400	48,400	52,000	43,400
Stocks, Dec. 31		2,860	2,990	2,510	2,770	W
Exports:						
Refined		177,000	217,000	157,000	217,000	169,000
Unmanufactured 4/		676,000	685,000	752,000	894,000	683,000
Imports:						
Refined		289,000	343,000	470,000	429,000	543,000
Unmanufactured 4/		593,000	637,000	763,000	825,000 r/	924,000
Copper stocks, Dec. 31:						
Blister and in-process material		166,000	146,000	171,000	174,000	173,000
Refined copper:						
Refineries		35,500	33,400	42,500	38,000	32,200
Wire rod mills		37,000	34,700	39,800	24,800	32,100
Brass mills		12,500	14,100	8,530	7,110	14,000
Other industry		23,800	3,650	4,090	3,030 r/	2,700
New York Commodity Exchange (COMEX)		96,000	67,200	24,200	21,500	26,600
London Metal Exchange (LME), U.S. warehouses.		--	--	--	68,200	38,300
Total refined		205,000	153,000	119,000	163,000	146,000
Consumption:						
Refined copper, reported		2,180,000	2,360,000	2,680,000	2,530,000	2,620,000
Apparent consumption, primary refined and old scrap		2,300,000	2,510,000	2,690,000	2,540,000	2,830,000
Price:						
Producer, weighted average	cents per pound	107.42	91.56	111.05	138.33	109.04
COMEX, first position	do.	102.72	85.28	107.05	134.72	105.87
LME, Grade A cash	do.	103.72	86.76	104.64	133.12	104.05
World production:						
Mine	thousand metric tons	9,470 r/	9,450 r/	9,500 r/	10,100 r/	11,000
Smelter	do.	9,920 r/	9,940 r/	10,100	10,200 r/	10,600
Refinery	do.	11,200	11,300 r/	11,200	11,900 r/	12,500

r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data, except prices, are rounded to three significant digits; may not add to totals shown.

2/ Yield calculations include precipitates but excludes copper recovered from leaching by solvent extraction-electrowinning.

3/ Includes primary copper produced from foreign ores, matte, and so forth, to avoid disclosing company proprietary data.

4/ Includes copper content of alloy scrap.

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TABLE 2
LEADING COPPER-PRODUCING MINES IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT 1/

Rank	Mine	County and State	Operator	Source of copper	Capacity (thousand metric tons)
1	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached.	475
2	Bingham Canyon	Salt Lake, UT	Kennecott Utah Copper Corp.	do.	320
3	Ray	Pinal, AZ	ASARCO Incorporated	Copper ore, concentrated and leached.	160
4	Chino	Grant, NM	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached.	160
5	Mission Complex	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated.	120
6	San Manuel	Pinal, AZ	BHP Copper Co.	Copper-molybdenum ore, concentrated and leached.	130
7	Sierrita	Pima, AZ	Cyprus Amax Minerals Co.	do.	135
8	Bagdad	Yavapai, AZ	do.	do.	110
9	Pinto Valley	Gila, AZ	BHP Copper Co.	do.	85
10	Tyrone	Grant, NM	Phelps Dodge Corp. and Burro Chief Copper Co.	Copper ore, concentrated and leached.	70
11	Inspiration	Gila, AZ	Cyprus Amax Minerals Co.	Copper ore, leached.	73
12	Continental	Silver Bow, MT	Montana Resources Inc.	Copper-molybdenum ore, concentrated.	50
13	Robinson	White Pine, NV	BHP Copper Co.	Copper ore, concentrated.	50
14	Continental	Grant, NM	Cobre Mining Co.	do.	35
15	Flambeau	Rusk, WI	Kennecott Minerals Corp.	do.	30
16	Casa Grande	Pinal, AZ	Cyprus Amax Minerals Co.	Copper ore, concentrated and leached.	20
17	Miami	Gila, AZ	BHP Copper Co.	Copper ore, leached.	12

1/ The mines in this list accounted for 98% of the U.S. mine production in 1996.

TABLE 3
MINE PRODUCTION OF COPPER-BEARING ORES AND RECOVERABLE COPPER CONTENT OF ORES PRODUCED IN THE UNITED STATES, BY SOURCE AND TREATMENT PROCESS

(Metric tons)

Source and treatment process	1995		1996	
	Gross weight	Recoverable copper	Gross weight	Recoverable copper
Mined copper ore:				
Concentrated	267,000,000	1,250,000	274,000,000 1/	1,290,000
Leached	NA	538,000 r/	NA	574,000
Total	NA	1,790,000	NA	1,860,000
Copper precipitates shipped; leached from tailings, dump, and in-place material	28,000	21,500	25,100	18,900
Other copper-bearing ores 2/	6,820,000	41,000	7,480,000	39,600
Grand total	XX	1,850,000	XX	1,920,000

r/ Revised. NA Not available. XX Not applicable.

1/ In 1996, 715,000 ounces of gold and 12,500,000 ounces of silver were recovered from concentrated ore. The average value of gold and silver per metric ton of ore concentrated was $1.25.

2/ Includes gold ore, gold-silver ore, lead ore, lead-copper ore, lead-zinc ore, molybdenum ore, silver ore, tungsten ore, zinc ore, fluorspar, flux ores, clean up, ore shipped directly to smelters, and tailings.

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TABLE 4
CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM 1/

(Metric tons)

Item	Brass mills	Wire-rod mills	Foundries, chemical plants, miscellaneous users	Smelters, refiners, ingot makers	Total
1995:					
Copper scrap	886,000 2/	(3/)	71,500	692,000 r/	1,650,000
Refined copper 4/	533,000	1,950,000	55,900 5/	(6/)	2,530,000
Hardeners and master alloys	1,030	--	1,970 r/	--	3,000
Brass ingots	--	--	120,000	--	120,000
Slab zinc	64,700	--	23,200 r/	3,580	91,500 r/
Miscellaneous	--	--	--	2	2
1996:					
Copper scrap	902,000 2/	(3/)	61,300	663,000	1,630,000
Refined copper 4/	588,000	1,980,000	49,400 5/	(6/)	2,620,000
Hardeners and master alloys	893	--	2,160	--	3,050
Brass ingots	--	--	121,000	--	121,000
Slab zinc	63,600	--	(7/)	(7/)	86,400
Miscellaneous	--	--	--	23	23

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes consumption of copper scrap at wire rod mills to avoid disclosing company proprietary data.

3/ Withheld to avoid disclosing company proprietary data; included in "Brass mills."

4/ Detailed information on consumption of refined copper can be found in table 5.

5/ Includes consumption of refined copper at ingot makers to avoid disclosing company proprietary data.

6/ Withheld to avoid disclosing company proprietary data; included in "Foundries, chemicals plants, and miscellaneous users."

7/ Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 5
CONSUMPTION OF REFINED COPPER SHAPES IN THE UNITED STATES, BY CLASS OF CONSUMER 1/

(Metric tons)

Class of consumer	Cathodes	Ingots and ingot bars	Cakes and slabs	Wirebar, billets, other	Total
1995:					
Wire-rod mills	1,950,000	--	--	--	1,950,000
Brass mills	298,000	27,800	75,900	130,000	533,000
Chemical plants	--	--	--	1,070	1,070
Ingotmakers	W	W	W	7,740	7,740
Foundries	2,380	3,440 r/	W	9,810 r/	15,600 r/
Miscellaneous 2/	W	W	W	31,400 r/	31,400
Total	2,250,000	31,300	75,900	181,000 r/	2,530,000
1996:					
Wire-rod mills	1,980,000	--	--	--	1,980,000
Brass mills	357,000	23,700	80,800	126,000	588,000
Chemical plants	--	--	--	1,110	1,110
Ingotmakers	W	--	W	3,640	3,640
Foundries	1,750	3,290	W	11,000	16,000
Miscellaneous 2/	W	W	W	28,600	28,600
Total	2,340,000	27,000	80,800	170,000	2,620,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Wirebar, billets, other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

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TABLE 6
COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1995	1996
Kind of scrap:		
New scrap:		
Copper-base	837,000	835,000
Aluminum-base	37,100	37,200
Nickel-base	85	91
Zinc-base	--	--
Total	874,000	872,000
Old scrap:		
Copper-base	415,000	394,000
Aluminum-base	27,900	33,100
Nickel-base	33	47
Zinc-base	21	17
Total	442,000	428,000
Grand total	1,320,000	1,300,000
Form of recovery:		
As unalloyed copper:		
At electrolytic plants	215,000	193,000
At other plants	149,000	151,000
Total	364,000	344,000
In brass and bronze	887,000	885,000
In alloy iron and steel	756	739
In aluminum alloys	64,700 r/	69,900
In other alloys	114	110
In chemical compounds	183	305
Total	953,000	956,000
Grand total	1,320,000	1,300,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 7
COPPER RECOVERED AS REFINED COPPER AND IN ALLOYS AND OTHER FORMS
FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF OPERATION 1/

(Metric tons)

	From new scrap		From old scrap		Total	
Type of operation	1995	1996	1995	1996	1995	1996
Ingot makers	34,700	36,200	89,300 r/	90200	124,000	126,000
Refineries 2/	112,000	111,000	240,000	222000	352,000	333000
Brass and wire-rod mills	664,000	670,000	49,300	46700	713,000	717000
Foundries and manufacturers	26,700	17,100	35,500	35900	62,200	53000
Chemical plants	183	305	--	--	183	305
Total	837,000	835,000	415,000 r/	394,000	1,250,000	1230000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Electrolytically refined and fire-refined scrap based on source of material at smelter level.

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TABLE 8
PRODUCTION OF SECONDARY COPPER AND COPPER-ALLOY PRODUCTS
IN THE UNITED STATES, BY ITEM PRODUCED FROM SCRAP 1/

(Metric tons)

Item produced from scrap	1995	1996
Unalloyed copper products:		
Electrolytically refined copper	215,000	193,000
Fire-refined copper	137,000	140,000
Copper powder	10,600	10,100
Copper castings	699	706
Total	364,000	344,000
Alloyed copper products:		
Brass and bronze ingots:		
Tin bronzes	11,900	12,500
Leaded red brass and semired brass	96,500	92,000
High leaded tin bronze	12,400	12,000
Yellow brass	6,700 r/	6,810
Manganese bronze	7,500 r/	7,400
Aluminum bronze	7,640	7,910
Nickel silver	1,760 r/	1,860
Silicon bronze and brass	5,280	5,630
Copper-base hardeners and master alloys	13,100	13,700
Miscellaneous	12 r/	11
Total	163,000	160,000
Brass mill and wire-rod mill products	873,000	888,000
Brass and bronze castings	52,900	44,000
Brass powder	530	634
Copper in chemical products	183	305
Grand total	1,450,000	1,440,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 9
COMPOSITION OF SECONDARY COPPER-ALLOY PRODUCTION IN THE UNITED STATES 1/

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production: 2/							
1995	132,000	4,990 r/	8,650 r/	17,000 r/	232	29	163,000
1996	130,000	4,800	8,010	16,300	264	26	160,000
Secondary metal content of brass mill products:							
1995	713,000	833	6,680	150,000	W	W	873,000
1996	717,000	886	7,270	160,000	W	W	888,000
Secondary metal content of brass and bronze castings:							
1995	47,400 r/	1,130	1,610	2,530	136	150	52,900
1996	39,000	1,050	1,460	2,330	85	120	44,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes about 96% from scrap and 4% from other than scrap.

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TABLE 10
CONSUMPTION AND YEAR ENDING STOCKS OF COPPER-BASE SCRAP 1/

(Metric tons, gross weight)

Scrap type and processor	1995		1996	
	Consumption	Stocks	Consumption	Stocks
No. 1 wire and heavy:				
Smelters, refiners, ingot makers	161,000	9,080	148,000	6,720
Brass and wire-rod mills	375,000	NA	355,000	NA
Foundries and miscellaneous manufacturers	36,000	NA	28,500	NA
No. 2 mixed heavy and light:				
Smelters, refiners, ingot makers	221,000 r/	5,880	217,000	7,950
Brass and wire-rod mills	33,400	NA	34,600	NA
Foundries and miscellaneous manufacturers	3,690	NA	3,880	NA
Total unalloyed scrap:				
Smelters, refiners, ingot makers	382,000 r/	15,000	366,000	14,700
Brass and wire-rod mills	408,000	11,600	390,000	14,200
Foundries and miscellaneous manufacturers	39,700	2,730	32,400	2,470
Red brass: 2/				
Smelters, refiners, ingot makers	58,800	2,440	58,600	2,250
Brass mills	7,410	NA	7,390	NA
Foundries and miscellaneous manufacturers	15,700	NA	15,100	NA
Leaded yellow brass:				
Smelters, refiners, ingot makers	26,100	1,270	27,400	1,500
Brass mills	341,000	NA	371,000	NA
Foundries and miscellaneous manufacturers	1,520	NA	1,930	NA
Yellow and low brass: All plants	55,600	723	59,600	725
Cartridge cases and brass: All plants	49,900	NA	46,100	NA
Auto radiators:				
Smelters, refiners, ingot makers	73,000	1,860	65,700	1,670
Foundries and miscellaneous manufacturers	6,910	NA	4,700	NA
Bronzes:				
Smelters, refiners, ingot makers	11,700	821	12,500	793
Brass mills and miscellaneous manufacturers	13,300	NA	13,400	NA
Nickel-copper alloys: All plants	20,500	442	23,300	360
Low grade and residues:				
Smelters, refiners and miscellaneous manufacturers	92,600	2,460	83,100	4,080
Other alloy scrap: 3/				
Smelters, refiners, ingot makers	39,700	1,600	42,000	2,410
Brass mills and miscellaneous manufacturers	6,140	NA	6,180	NA
Total alloyed scrap:				
Smelters, refiners, ingot makers	310,000	11,600	297,000	13,800
Brass mills	478,000	29,900	512,000	25,100
Foundries and miscellaneous manufacturers	31,800	4,020 r/	28,900	3,570
Total scrap:				
Smelters, refiners, ingot makers	692,000 r/	26,600	663,000	28,400
Brass and wire-rod mills	886,000	41,400	902,000	39,300
Foundries and miscellaneous manufacturers	71,500	6,740 r/	61,300	6,050

r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes composition turnings, silicon bronze, railroad car boxes, cocks and faucets, gilding metal, and commercial bronze.

3/ Includes refinery brass, beryllium copper, and aluminum bronze.

TABLE 11
CONSUMPTION OF PURCHASED COPPER-BASE SCRAP 1/ 2/

(Metric tons, gross weight)

Type of operation	From new scrap		From old scrap		Total	
	1995	1996	1995	1996	1995	1996
Ingot makers	46,400	47,700	136,000	126,000	182,000	174,000
Smelters and refineries	129,000 r/	130,000	381,000 r/	359,000	510,000 r/	489,000
Brass and wire-rod mills	827,000	845,000	59,400	57,700	886,000	902,000
Foundries and miscellaneous manufacturers	30,800	21,000	40,700 r/	40,200	71,500	61,300
Total	1,030,000	1,040,000	617,000 r/	583,000	1,650,000	1,630,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Consumption at brass and wire-rod mills assumed to be equal to receipts.

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TABLE 12
FOUNDRIES AND MISCELLANEOUS MANUFACTURERS CONSUMPTION
OF BRASS INGOT AND REFINED COPPER AND COPPER SCRAP
IN THE UNITED STATES 1/

(Metric tons)

Ingot type	1995	1996
Tin bronzes	35,100	33,900
Leaded red brass and semired brass	68,400 r/	70,200
Yellow, leaded, and low brass 2/	7,310	8,330
Manganese bronze	4,230 r/	3,710
Nickel silver 3/	1,210 r/	960
Aluminum bronze	3,770 r/	3,590
Hardeners and master alloys 4/	1,970 r/	2,160
Total brass ingot	122,000	123,000
Refined copper consumed	48,100 r/	45,700
Copper scrap consumed	71,500 r/	61,300

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes silicon bronze and brass.
3/ Includes copper nickel and nickel bronze and brass.
4/ Includes special alloys.

TABLE 13
AVERAGE PRICES FOR COPPER SCRAP AND ALLOY-INGOT, BY TYPE

(Cents per pound)

			Dealers' buying (New York)		Alloy-ingot (New York)	
Year	Brass mills No. 1 scrap	Refiners No. 2 scrap	No. 2 scrap	Red brass turnings and borings	No. 115 brass (85-5-5-5)	Yellow brass (405)
1995	123.28	104.73	91.26	63.38	137.38	135.14
1996	101.53	84.42	75.27	51.85	140.25	136.50

Source: American Metal Market.

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TABLE 14
U.S. EXPORTS OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY 1/

Country	Ore and concentrate		Matte, ash, and precipitates		Refined		Unalloyed copper scrap		Blister and anodes		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995	239,000	$438,000	35,100	$43,300	217,000	$616,000	223,000	$403,000	29,200	$79,700	743,000	$1,580,000
1996:												
Belgium	--	--	3	3	46	71	9,380	20,200	239	368	9,660	20,700
Canada	79,900	124,000	31,500	38,200	28,500	70,100	104,000	170,000	17,900	42,000	262,000	443,000
China	54,500	30,700	2	3	233	447	12,600	18,900	44	50	67,400	50,100
Germany	76	211	1	8	189	372	7,190	10,700	463	1,200	7,920	12,500
Hong Kong	16	24	29	41	525	837	28,600	41,200	1,170	2,240	30,300	44,300
India	--	--	271	297	7	19	3,960	3,740	3	5	4,250	4,060
Italy	8	3	2	3	2,150	3,460	22	32	451	1,070	2,640	4,570
Japan	47,600	59,600	2,130	14,300	31,800	77,400	19,300	61,000	456	1,130	101,000	214,000
Korea, Republic of	1,570	2,420	19	62	3,480	6,730	5,140	11,600	1,100	10,200	11,300	31,100
Malaysia	--	--	--	--	6,470	15,200	34	59	(2/)	5	6,510	15,300
Mexico	2,340	1,310	2,790	4,170	11,800	26,300	2,470	4,010	380	686	19,700	36,500
Singapore	--	--	8	118	2,690	6,200	234	378	44	148	2,980	6,850
Spain	2,800	3,410	6	24	7	10	39	62	15	21	2,870	3,520
Switzerland	--	--	--	--	23	35	2,760	2,590	(2/)	3	2,780	2,630
Taiwan	--	--	--	--	54,100	128,000	1,340	2,200	330	582	55,800	131,000
Thailand	--	--	--	--	26,100	63,200	37	46	112	286	26,200	63,500
Other	6,370	8,180	230	485	1,030	3,170	538	3,700	390	991	8,560	16,500
Total	195,000	230,000	37,000	57,700	169,000	401,000	197,000	350,000	23,100	61,000	622,000	1,100,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 15
U.S EXPORTS OF COPPER SEMIMANUFACTURES, BY COUNTRY 1/

Country	Pipes and tubing		Plates, sheets, foil, and bars		Bare wire, including wire rod 2/		Wire and cable, stranded		Copper sulfate	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995	21,700	$88,500	36,200	$145,000	34,300	$115,000	8,760	$54,900	3,080	$3,440
1996:										
Australia	217	1,220	14	58	11	80	46	288	5	4
Austria	67	374	616	1,650	11	129	(3/)	13	--	--
Brazil	144	1,510	19	116	50	202	401	1,950	--	--
Canada	7,650	26,700	12,900	43,200	14,900	43,500	2,920	10,500	2,050	2,070
China	1,020	5,160	309	1,690	29	294	84	646	--	--
Costa Rica	21	85	511	1,830	4	16	35	264	32	25
Dominican Republic	31	65	3	15	1,910	4,950	115	517	9	12
France	117	790	11	68	81	679	112	2,310	--	--
Germany	10	74	649	2,740	130	1,680	163	3,320	--	--
Hong Kong	680	2,590	1,250	9,820	159	1,320	279	2,270	--	--
India	201	625	188	326	21	87	72	644	--	--
Indonesia	84	264	361	784	--	--	218	2,700	--	--
Israel	259	1,640	76	461	45	401	104	588	--	--
Italy	727	3,220	441	1,700	1	44	239	1,990	--	--
Japan	223	1,030	10,100	31,800	3,070	7,200	139	2,060	--	--
Korea, Republic of	357	1,520	956	6,420	28	504	66	563	--	--
Malaysia	751	3,400	1,170	3,990	601	1,690	19	164	--	--
Mexico	6,920	21,900	6,030	21,200	14,500	45,100	1,490	5,490	5	10
Netherlands	380	1,520	68	269	9	105	28	426	--	--
Philippines	241	964	99	363	63	308	115	797	12	10
Saudi Arabia	483	1,950	30	152	33	151	376	3,600	--	--
Singapore	62	284	238	1,560	59	444	37	377	--	--
Spain	349	990	20	208	5	48	1	27	--	--
Sweden	--	--	(3/)	8	12	196	20	153	--	--
Taiwan	715	2,450	9,200	32,400	234	1,480	34	616	69	55
Thailand	751	3,170	1,510	4,470	283	966	19	203	--	--
Trinidad and Tobago	--	--	5	38	1,040	2,870	51	175	--	--
United Kingdom	215	2,060	448	1,490	137	1,120	284	3,740	6	9
Venezuela	149	656	85	383	208	509	148	802	--	--
Other	1,840	7,500	938	4,850	1,070	5,250	1,450	8,930	139	134
Total	24,700	93,700	48,200	174,000	38,700	121,000	9,070	56,100	2,320	2,320

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Total exports of wire rod were 12,900 tons valued at $30,700,000 in 1995 and 15,000 tons valued at $34,500,000 in 1996.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY 1/

Country	Ore and concentrate		Matte, ash, and precipitates		Blister and anode		Refined		Unalloyed scrap		Total	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
1995	127,000	$129,000	2,860	$3,550	94,100	$257,000	429,000	$1,290,000	88,100 r/	$192,000 r/	741,000 r/	$1,870,000 r/
1996:												
Brazil	--	--	--	--	--	--	15,600	39,200	--	--	15,600	39,200
Canada	9,000	16,300	236	466	80,200	87,900	278,000	847,000	40,500	73,200	408,000	1,020,000
Chile	59,800	51,800	--	--	51,700	127,000	119,000	264,000	11,800	27,900	242,000	471,000
Colombia	--	--	--	--	--	--	540	1,400	668	1,270	1,210	2,670
Costa Rica	--	--	--	--	--	--	--	--	1,320	2,460	1,320	2,460
Germany	--	--	--	--	--	--	9,960	20,700	102	29	10,100	20,700
Japan	--	--	--	--	(3/)	2	3,940	10,600	2	26	3,940	10,600
Kazakstan	--	--	--	--	--	--	2,630	6,470	--	--	2,630	6,470
Malaysia	--	--	79	233	--	--	--	--	--	--	79	233
Mexico	3,680	4,360	2,050	1,790	19,600	48,000	30,300	79,000	27,900	52,200	83,500	185,000
Peru	--	--	--	--	9,550	21,900	64,700	131,000	785	1,450	75,000	155,000
Russia	--	--	--	--	--	--	15,000	32,000	--	--	15,000	32,000
Spain	--	--	--	--	2,710	2,610	--	--	138	210	2,850	2,820
Taiwan	--	--	24	111	--	--	(3/)	6	102	130	126	247
Uzbekistan	--	--	--	--	--	--	3,570	8,150	--	--	3,570	8,150
Venezuela	--	--	--	--	--	--	--	--	2,600	3,990	2,600	3,990
Other	3	16	2	20	649	1,360	308	1,020	4,440	7,460	5,400	9,870
Total	72,400	72,500	2,390	2,620	164,000	289,000	543,000	1,440,000	90,300	170,000	873,000	1,980,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ C.i.f. value at U.S. port.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 17
U.S. IMPORTS FOR CONSUMPTION OF COPPER SEMIMANUFACTURES, BY COUNTRY 1/

Country	Pipes and tubing		Plates, sheets, foil, and bars		Bare wire, including wire rod		Wire and cable, stranded		Copper sulfate	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
1995	103	$869	57,000	$256,000	41,800	$137,000	3,540	$21,900	12,400	$11,900
1996:										
Australia	--	--	80	307	--	--	--	--	--	--
Austria	--	--	151	386	9	141	6	84	3	4
Brazil	--	--	600	2,100	--	--	--	--	(3/)	3
Canada	61	266	13,700	49,000	54,400	135,000	50	145	4,240	3,860
Chile	6	21	1,020	3,260	--	--	--	--	391	375
China	--	--	773	2,930	1,130	3,420	17	105	878	852
Finland	1	4	4,060	16,300	244	1,300	(3/)	3	--	--
France	--	--	286	1,110	136	1,860	94	819	--	--
Germany	458	2,830	8,890	36,900	72	809	194	1,750	43	68
Israel	--	--	1	25	--	--	2,340	14,700	1,200	1,120
Italy	--	--	140	436	26	209	19	215	56	58
Japan	(3/)	4	9,160	45,600	77	1,390	96	1,110	8	72
Luxembourg	--	--	610	6,460	--	--	--	--	--	--
Malaysia	--	--	876	7,250	3	60	--	--	--	--
Mexico	65	189	1,400	4,880	155	523	32	99	9,550	8,620
Netherlands	1	5	570	2,300	9	161	--	--	--	--
Peru	--	--	2,580	4,780	--	--	--	--	1,010	855
Sweden	--	--	12,500	51,600	22	80	2	53	--	--
Turkey	--	--	2	5	522	2,070	27	154	--	--
United Kingdom	2	30	606	4,900	7	101	4	125	--	--
Venezuela	--	--	66	232	8	6	1,590	4,410	--	--
Other	17	110	559	4,280	190	1,750	153	1,380	42	38
Total	611	3,460	58,700	245,000	57,000	149,000	4,620	25,200	17,400	15,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C.i.f. value at U.S. port.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 18
U.S. EXPORTS OF COPPER SCRAP, BY COUNTRY 1/

	Unalloyed copper scrap				Copper-alloy scrap			
	1995		1996		1995		1996	
Country or Territory	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	2,730	$10,100	9,380	$20,200	3,030	$9,730	1,440	$3,710
Canada	110,000	191,000	104,000	170,000	42,600	60,900	41,900	$53,900
China	28,000	40,300	12,600	18,900	50,100	50,100	24,900	27,400
Germany	1,580	1,820	7,190	10,700	4,310 r/	8,240	5,290	5,660
Hong Kong	31,400	47,900	28,600	41,200	30,900	41,000	43,200	62,900
India	7,020	7,520	3,960	3,740	42,500	48,900	29,800	31,600
Japan	20,000	64,800	19,300	61,000	16,700	34,600	18,700	33,700
Korea, Republic of	10,300	19,900	5,140	11,600	24,100	35,800	11,200	19,400
Mexico	6,470	11,000	2,470	4,010	1,710	3,050	4,030	6,000
Switzerland	17	39	2,760	2,590	56	97	18	28
Taiwan	1,680	2,490	1,340	2,200	3,730	4,910	4,970	6,460
Thailand	--	--	37	46	2,490	3,650	2,460	4,190
United Kingdom	338	510	194	2,970	2,810	5,620	381	792
Other	3,570 r/	5,070 r/	673	1,250	8,350 r/	12,400 r/	7,030	10,500
Total	223,000	403,000	197,000	350,000	233,000	319,000	195,000	266,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 19
U.S. IMPORTS FOR CONSUMPTION OF COPPER SCRAP, BY COUNTRY 1/

	Unalloyed copper scrap		Copper-alloy scrap		
	Quantity	Value 2/	Gross weight	Copper content e/ 3/	Value
Country or Territory	(metric tons)	(thousands)	(metric tons)	(metric tons)	(thousands)
1995	88,100 r/	$192,000 r/	95,100 r/	68,900 r/	$208,000 r/
1996:					
Canada	40,500	73,200	57,700	41,500	80,400
Chile	11,800	27,900	178	128	275
Colombia	668	1,270	3,020	2,170	5,950
Costa Rica	1,320	2,460	386	278	351
Dominican Republic	603	1,130	1,940	1,390	3,730
Ecuador	29	55	872	628	1,680
Honduras	275	529	1,040	752	1,510
Jamaica	710	1,100	592	426	531
Mexico	27,900	52,200	42,400	30,500	59,800
Panama	1,020	1,850	1,100	792	1,290
Peru	785	1,450	784	564	919
Taiwan	102	130	1,480	1,060	1,450
United Kingdom	(4/)	5	1,310	945	1,450
Venezuela	2,600	3,990	2,540	1,830	3,240
Other	2,050	3,050	6,490	4,670	8,050
Total	90,300	170,000	122,000	87,700	171,000

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C. i. f. value at U.S. Port.
3/ Under the Harmonized Tariff System that was implemented January 1989, copper content is no longer available. Content is estimated to be 72% of gross weight.
4/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 20
COPPER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Albania	900	900	800	800 e/	800
Argentina e/	300 3/	300	300	300	300
Armenia e/	1,000 r/	500	1,000 r/	3,500 r/	4,000
Australia:					
By concentration or cementation	363,500 r/	384,000 r/	392,000 r/	379,700 r/	471,000
Leaching (electrowon)	14,500 r/	18,000 r/	23,600 r/	40,200 r/	53,800
Total	378,000	402,000	415,600	419,900	525,000
Bolivia	101	94	79	127	105
Botswana 4/	20,400	20,132	22,780	21,029	20,900 3/
Brazil	39,845	43,568 r/	39,690	47,933 r/	26,400 3/
Bulgaria	47,400	60,400	73,900 r/	75,400 r/	88,700 3/
Burma	3,731	3,581	5,025	5,282 r/	5,500
Canada:					
By concentration or cementation	765,500	729,900	615,000	726,380	686,339 3/
Leaching (electrowon)	3,100	2,700	2,300	2,300	2,500 3/
Total	768,600	732,600	617,300	728,680	688,839 3/
Chile 5/	1,932,700	2,055,400	2,219,900	2,488,600 r/	3,115,800 3/
China e/	334,000	345,000	396,000	445,000 r/	439,100 3/
Colombia e/	3,940 3/	-- r/	1,000 r/	1,400 r/	2,800
Cuba e/	1,500	1,500	1,400	1,500	1,500
Cyprus	--	--	--	--	1,688 3/
Czechoslovakia 6/ 7/	2,500 e/	XX	XX	XX	XX
Ecuador e/	100	100 r/	100 r/	100 r/	100
Finland	10,246	11,131	9,790 r/	9,500 r/ e/	9,000
France	149	72	50 r/	--	--
Georgia e/	5,000	3,000	2,000	1,000	1,000
Honduras e/	1,600 3/	1,000	500	390	-- 3/
India	49,036	49,416	45,944	46,975 r/	35,800 3/
Indonesia 6/	280,819	298,648	322,190	443,618	507,484 3/
Iran	105,000	86,600	117,900 r/	102,200 r/	107,600 3/
Japan	12,074	10,277	6,043	2,376	1,145 3/
Kazakstan e/	270,000 r/	300,000	265,000 r/	240,000 r/	250,000
Korea, North e/	16,000	16,000	16,000	16,000	16,000
Korea, Republic of	4	5	5 e/	31 r/	7 3/
Macedonia	7,200 e/	5,800	6,500	6,500 e/	6,500
Malaysia	28,556	25,182	25,267	20,751 r/	22,771 3/
Mexico:					
By concentration or cementation	251,100	277,000	279,700	304,300	297,710 3/
Leaching (electrowon)	27,900	24,100	25,800	38,900 r/	43,000 3/
Total	279,000	301,100	305,500	343,200	340,710 3/
Mongolia	105,100	96,900	99,600	100,400	101,900 3/
Morocco	14,300	12,990	13,020	14,000 r/	14,300 3/
Namibia	31,300	29,500	26,555	22,530	14,904 3/
Nepal	2	2	2 e/	2 e/	2
Norway	12,668	8,696	7,408	6,799	7,000
Oman	13,600	8,800 r/	4,300 r/	--	-- 3/
Papua New Guinea	193,359	203,945	209,329 r/	212,737	186,715 3/
Peru: 8/					
By concentration or cementation	327,200	328,000	326,400	409,693 r/	484,231 3/
Leaching (electrowon)	18,400	20,300	17,200	33,392 r/	88,171 3/
Total	345,600	348,300	343,600	443,085	572,402 3/
Philippines	123,523	136,257	116,163 r/	108,063 r/	61,600 3/
Poland	331,900	383,600	378,000	383,600	422,000 3/
Portugal	152,311	153,797	133,629	134,181	110,000
Romania 6/	24,700	25,300	26,034	24,528 r/	24,310 3/
Russia	698,500	583,600	573,300	525,000 r/	520,000
Saudi Arabia	868	925	917	925 e/	900
Serbia and Montenegro	97,811	68,007	65,000	87,575 r/	82,526 3/
Slovakia e/ 9/	XX	500	-- r/	-- r/	386 3/
South Africa	176,074	166,348	160,100 r/	161,600 r/	152,595 3/
Spain	9,432	6,691 r/	5,944 r/	22,112 r/	25,000
Sweden	89,145	88,909	79,384	83,600 e/	72,900
Turkey 10/	38,554	39,163	34,902	37,900 r/	45,000

See footnotes at end of table.

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TABLE 20--Continued
COPPER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
United States: 6/					
By concentration or cementation	1,260,000	1,310,000	1,320,000	1,310,000	1,340,000 3/
Leaching (electrowon) 11/	502,000	491,000	493,000	539,000	574,000 3/
Total	1,760,000	1,800,000	1,820,000	1,850,000	1,920,000 3/
Uzbekistan e/	75,000	65,000 r/	80,000 r/	50,000 r/	65,000
Zaire: 6/					
By concentration or cementation	21,900	6,900 r/	7,200 r/	6,800	6,200
Leaching (electrowon)	111,000	39,400 r/	22,800 r/	22,600 r/	22,600
Total	132,900	46,300 r/	30,000 r/	29,400 r/	28,800
Zambia: 12/					
By concentration or cementation (smelted)	321,800	284,900	289,800 r/	268,900 r/	279,000
Leaching (electrowon)	107,700	111,300	83,400 r/	54,800 r/	55,000
Total	429,500	396,200	373,200 r/	323,700 r/	334,000
Zimbabwe: 6/					
By concentration or cementation	10,100	8,200 r/	9,350	7,900 r/	9,000
Leaching (electrowon)	--	--	--	200	3,200
Total	10,100	8,200 r/	9,350	8,100 r/	12,200
Grand total	9,470,000 r/	9,450,000 r/	9,500,000 r/	10,100,000 r/	11,000,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Data represent copper content by analysis of concentrates produced except where otherwise noted. Table includes data available through July 10, 1997.

3/ Reported figure.

4/ Copper content of pelletized nickel-copper matte produced in smelter.

5/ Reported by Comision Chilena del Cobre (COCHILCO). Includes recoverable copper content of nonduplicative mine and metal products produced from domestic ores and concentrates, and leach production for electrowinning.

6/ Recoverable content.

7/ Dissolved Dec. 31, 1992. Production in Czechoslovakia for 1992 came from Slovakia.

8/ Prior to 1993 nonduplicative shipments of concentrates, smelter and refinery products. Beyond 1992, recoverable mine production sourced from Ministry Energy and Mines, General Directorate of Mines.

9/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

10/ Excludes copper content of pyrite.

11/ Includes electrowon from concentrates roast-leached.

12/ Data are for fiscal years beginning Apr. 1 of year stated. Zambian-mined copper reported recovered during smelting and electrowinning.

TABLE 21
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Albania, primary	2,300	2,300	1,500 e/	3,000 r/ e/	2,400
Australia:					
Primary	304,300	323,100	315,000 e/	215,000 r/	289,000
Secondary e/	10,000	10,000	9,600 r/	1,200 r/	1,200
Total e/	314,000	333,000	325,000	216,000 r/	290,000
Austria, secondary	48,975	46,856	49,562	53,400 e/	65,400
Belgium: e/					
Primary	800	200	2,600	2,700 r/	3,500
Secondary	102,000	142,000	145,000	152,000 r/	154,000
Total	103,000	142,000	148,000	155,000 r/	157,300 4/
Brazil, primary	157,950	161,102	170,033	164,966 r/	165,000
Bulgaria: e/					
Primary	61,000	58,500	84,400 r/	87,200 r/	95,300
Secondary	5,000	5,000	5,000	5,000	5,000
Total	66,000	63,500	89,400 r/	92,200 r/	100,000
Canada:					
Primary	515,000	518,000	515,000	522,761 r/	529,349 p/
Secondary	37,400	44,100	45,000 e/	90,929	83,344 p/
Total	552,400	562,100	560,000 e/	613,690 r/	612,693 p/
Chile, primary 5/	1,191,000	1,234,000	1,259,400	1,293,800	1,355,600 p/

See footnotes at end of table.

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TABLE 21--Continued
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
China: e/					
Primary	418,000	443,000	482,000	538,000 r/	615,600 4/
Secondary	128,000	183,000	212,000	466,000 r/	382,000
Total	546,000	626,000	694,000	1,000,000 r/	998,000
Czech Republic, primary 6/	XX	500	-- e/	--	--
Czechoslovakia: 7/					
Primary e/	5,000	XX	XX	XX	XX
Secondary e/	3,000	XX	XX	XX	XX
Total	8,000	XX	XX	XX	XX
Finland:					
Primary	110,502	107,201	129,265	130,000 e/	125,000
Secondary e/	12,000	12,000	12,000	12,000	15,000
Total e/	123,000	119,000	141,000	142,000	140,000
France, secondary e/	6,100	5 900	4 400	2 600 r/	3 100
Germany:					
Primary	164,900	141,300	237,400	242,100	297,000
Secondary e/	70,000	60,000	54,800 4/	66,000	88,600
Total e/	235,000 r/	201,000	292,200 4/	308,000	385,400 4/
Hungary, secondary e/	100	100	100	100	100
India, primary	47,712	37,372	51,232	39,496 r/	28,286 4/
Iran: 8/					
Primary	86,400	85,000	125,000	100,000 r/	91,300
Secondary e/	6,400	7,000	6,800 r/	6,100 r/	6,000
Total	92,800 e/	92,000 e/	131,800 r/	106,100 r/	97,300
Japan:					
Primary	1,046,200	1,099,100	1,025,500	1,081,200 r/	1,134,100 4/
Secondary	128,700	85,700	96,500	87,300 r/	89,300 4/
Total	1,174,900	1,184,800	1,122,000	1,168,500	1,223,400 4/
Kazakstan: e/					
Primary	300,000	280,000 r/	275,000	242,800 r/ 4/	245,000 4/
Secondary	20,000	20,000	20,000	20,000	20,000
Total	320,000	300,000 r/	295,000	263,000 r/	265,000
Korea, North: e/					
Primary	21,000	23,000	23,000	24,000	24,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	26,000	28,000	28,000	29,000	29,000
Korea, Republic of, primary e/	170,100 4/	142,000	160,000	165,000	165,000
Mexico, primary	228,200	282,000	277,000	298,000	300,800 4/
Namibia, primary 9/	37,500	34,800 e/	29,781	29,799	25,100
Norway, primary	39,259	37,205	39,416	31,146 r/	36,000
Oman, primary	14,973	27,700	31,200	34,200	34,800 4/
Peru, primary	336,000	343,400	349,900	345,119 r/	323,707 4/
Philippines, primary	168,831	212,446 r/	200,255 r/	158,109 r/	155,800 4/
Poland:					
Primary	385,486	396,000 e/	388,600 r/	374,600 r/	375,000
Secondary e/	15,963 4/	16,000	15,000	15,000	15,000
Total e/	401,449 4/	412,000	404,000 r/	390,000 r/	390,000
Portugal, secondary e/	1,000	1,000	--	--	--
Romania: e/					
Primary	23,400 4/	25,200	23,449 4/	23,345 4/	32,562 4/
Secondary	1,000	1,000	1,000	1,000	1,000
Total	24,400	26,200	24,400 r/	24,300	33,600
Russia:					
Primary	651,000 r/	533,700 r/	514,300 r/	512,000 r/	510,000
Secondary	50,000 r/	40,000 r/	15,000 r/	40,000 r/	55,000
Total	701,000 r/	573,700 r/	529,300 r/	552,000 r/	565,000
Serbia and Montenegro:					
Primary	79,953	44,112	69,000	70,074	59,940 4/
Secondary	47,967	13,286	17,400	17,336	65,287 4/
Total	127,920	57,398	86,400	87,410	125,227 4/
Slovakia, primary e/ 6/	XX	3,000	3,000	3,000	3,000
South Africa, primary	158,700	156,600	165,900	154,400	148,400 4/

See footnotes at end of table.

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TABLE 21--Continued
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Spain:					
Primary	110,000	135,700	141,600	134,000 e/	130,000
Secondary	37,000	44,800	46,800	47,100 e/	50,000
Total	147,000	180,500	188,400	181,000 e/	180,000
Sweden:					
Primary	77,804	76,298	79,100 e/	78,000 e/	80,000
Secondary	20,596	22,102	19,600 e/	20,000 e/	20,000
Total	98,400	98,400	98,700 e/	98,000 e/	100,000
Turkey, undifferentiated 10/	31,568	39,638	30,400	33,700 e/	35,000
United States:					
Primary 11/	1,180,000	1,270,000	1,310,000	1,250,000 r/	1,300,000 4/
Secondary	394,000	415,000	397,000	354,000 r/	339,000 4/
Total	1,570,000	1,680,000	1,710,000	1,600,000 r/	1,640,000 4/
Uzbekistan: e/					
Primary	75,000 r/	65,000	80,000 r/	50,000 r/	65,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	80,000 r/	70,000	85,000 r/	55,000 r/	70,000
Zaire, primary: e/					
Electrowon	111,000	40,000	22,800	22,000	22,000
Other	19,900	6,500	7,200	5,600	6,000
Total	131,000	46,500	30,000	27,600	28,000
Zambia, primary: 12/					
Electrowon	63,980	62,414	26,700	65,400 r/	73,900
Other	356,367	305,146	241,000 r/	234,500 r/	250,000
Total	420,347	367,560	267,700 r/	299,900 r/	324,000
Zimbabwe, primary e/ 13/	9,700	8,200	10,100	12,000	12,000
Grand total	9,920,000 r/	9,940,000 r/	10,100,000	10,200,000 r/	10,600,000
Of which:					
Primary:					
Electrowon	175,000	102,000	49,500	87,400 r/	95,900
Other	8,550,000 r/	8,610,000 r/	8,820,000 r/	8,650,000 r/	9,010,000
Secondary	1,160,000 r/	1,180,000 r/	1,180,000	1,470,000 r/	1,470,000
Undifferentiated	31,600	39,600	30,400	33,700	35,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 10, 1997.

3/ Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper, and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.

4/ Reported figure.

5/ Data include low-grade electrowon which is re-refined. Low-grade electrowon production is as follows, in thousand metric tons: 1992--31.1; 1993--28.7; 1994--24.5; and 1995-96--not available.

6/ Formerly part of Czechoslovakia; data not reported separately until 1993.

7/ Dissolved Dec. 31, 1992.

8/ Data are for year beginning Mar. 21 of year stated. Secondary production is estimated to be about 5% of total.

9/ Includes products of imported concentrate.

10/ Secondary production is estimated to be about 5% to 10% of total.

11/ Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire-refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1992--27,196; 1993--19,043; 1994--26,400; 1995--21,500; and 1996--18,900.

12/ For fiscal year beginning Apr. 1 of year stated. Electrowon is total electrowon production reported, less the quantity reported as "finished production, leach cathodes."

13/ Includes impure cathodes produced by electrowinning in nickel processing.

11/ May include copper-nickel matte (copper content more than 6,000 tons per year) imported from Botswana for toll refining.

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TABLE 22
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Albania, primary e/	1,500	1,500	1,000	1,000	1,000
Argentina, secondary e/	15,000	15,000	14,400 r/ 3/	16,000 r/ 3/	15,500
Australia:					
Primary	271,000	285,000	311,900	242,000 r/	314,000 3/
Secondary	32,000	24,000	24,000	18,000 r/ e/	--
Total	303,000	309,000	335,900	260,000 r/ e/	314,000 3/
Austria:					
Primary	5,705	5,871	2,904	530 r/ e/	1,000
Secondary	48,975	46,856	49,562	53,000 r/ e/	57,000
Total	54,680	52,727	52,466	53,500 r/ e/	58,000
Belgium: 4/					
Primary	253,318	275,900	227,600	159,000 r/	137,000 3/
Secondary	114,000	103,000	147,600	217,000 r/	217,000 3/
Total	367,318	378,900	375,200	376,000 r/	354,000 3/
Brazil, primary	157,950	161,102	170,033	164,966	172,000 3/
Bulgaria:					
Primary e/	13,008 3/	24,300	21,500	25,500 r/	25,000
Secondary e/	5,000	2,000	5,000	3,330 r/	5,000
Total	18,008	26,347	26,500	28,800 r/	30,000
Canada:					
Primary	501,900	521,200	504,600	479,100 r/	477,500 3/
Secondary	37,400	40,400	45,400	93,500 r/	81,700 3/
Total	539,300	561,600	550,000	572,600 r/	559,200 3/
Chile, primary	1,242,300	1,268,200	1,277,400 r/	1,491,500 r/	1,748,200 p/
China: e/					
Primary	430,000	485,000	482,000	612,000 r/	692,000
Secondary	229,000	245,000	254,000	467,000 r/	428,000
Total	659,000	730,000	736,000	1,080,000 r/	1,120,000
Czech Republic, primary 5/	XX	500	--	--	--
Czechoslovakia: 6/					
Primary	8,000	XX	XX	XX	XX
Secondary	20,561	XX	XX	XX	XX
Total	28,561	XX	XX	XX	XX
Egypt, secondary e/	4,000	4,000	4,000	4,000	4,600
Finland:					
Primary	65,900	67,700	58,400	63,700 r/ e/	64,000
Secondary	5,000	6,000	10,800	10,000 e/	10,000
Total	70,900	73,700	69,200	73,700 r/ e/	74,000
France:					
Primary e/	16,600	18,400	16,600	4,200 r/	10,500
Secondary e/	26,200	26,000	25,200	38,300 r/	28,600
Total	42,800	44,400	41,800	42,500 r/ e/	39,100
Germany:					
Primary	236,282	270,592	253,000 e/	247,200	316,000
Secondary e/	345,000	361,000	339,000	369,100 3/	355,000
Total	581,682	632,079	591,859	616,300	671,000
Hungary, primary and secondary e/	12,000	11,000	11,000	11,000	11,000
India:					
Primary: Electrolytic	38,300	30,100	40,100	33,900 r/	29,100 3/
Secondary	8,500	6,700	8,900	7,300 e/	6,500
Total e/	46,800	36,800	49,000	41,200 r/	35,600
Iran, primary 7/ 8/	101,800	84,900	90,200	90,400 r/	99,100 3/
Italy, primary and secondary	76,000 e/	90,300	84,000	98,000 e/	85,800 3/
Japan:					
Primary	1,046,155	1,099,083	1,025,510	1,081,235 r/	1,134,060 3/
Secondary	114,704	89,693	93,658	106,724 r/	117,313 3/
Total	1,160,859	1,188,776	1,119,168	1,187,959	1,251,373 3/
Kazakstan: e/					
Primary	300,000 r/	290,000 r/	280,000 r/ 3/	255,600 r/ 3/	263,300 3/
Secondary	20,000	20,000	20,000	20,000	20,000
Total	320,000 r/	310,000 r/	300,000 r/	276,000 r/	283,000

See footnotes at end of table.

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TABLE 22--Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Korea, North: e/					
Primary	20,000	22,000	22,000	22,000	23,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	25,000	27,000	27,000	27,000	28,000
Korea, Republic of:					
Primary	209,000	218,000	244,169 r/	234,895 r/	246,305 3/
Secondary e/	2,000	2,000	2,000	2,000	2,000
Total e/	211,000 3/	220,000	246,000 r/	237,000 r/	248,000
Mexico:					
Primary:					
Electrowon	27,940	24,100	25,800	27,600	43,000 3/
Other	82,600	69,800	78,500	75,500	64,200
Secondary	80,500	77,200	92,700	98,800 e/	96,400 3/
Total	191,040	171,100	197,000	202,000 e/	204,000
Norway, primary 8/	39,259	37,205	39,416	34,322 r/	28,526 3/
Oman, primary	16,236	20,539	24,194	21,300 r/	21,600
Peru, primary	252,647 r/	258,934 r/	265,413 r/	295,100 r/	338,100 3/
Philippines, primary	145,674 r/	165,954	154,713	158,109 r/	82,972 3/
Poland:					
Primary	387,010	404,170	405,093	406,708 r/	425,000
Secondary	67,420	56,989	20,318 r/	28,976 r/	20,000
Total	454,430	461,159	425,411	435,684 r/	445,000
Romania: e/					
Primary	21,000	22,000	22,113 3/	22,013 r/ 3/	28,323 3/
Secondary	3,080	3,000	4,600	1,000	1,000
Total	24,100	25,000	26,700	23,000 r/	29,300
Russia:					
Primary e/	525,000	522,000	481,000	519,000 r/	545,000
Secondary e/	50,000	40,000	15,000 r/	41,700 r/	25,000
Total	575,400	562,000	496,000 r/	560,300 r/	570,000
Serbia and Montenegro:					
Primary	78,560	43,410	66,308 r/	71,304 r/	59,940 3/
Secondary	36,203	7,890	5,841 r/	7,147 r/	44,060 3/
Total	114,763	51,300	72,149	78,451 r/	104,000 3/
Slovakia, primary and secondary 5/	XX	28,000	25,000	25,000 e/	25,000
South Africa, primary 8/	120,100	127,900	129,622	124,300	130,000
Spain:					
Primary	134,325	137,230	142,000 e/	117,000 e/	210,000
Secondary	44,775	42,000	46,800 e/	47,100 e/	54,000
Total	179,100	179,230	188,000 e/	164,000 r/	264,000
Sweden:					
Primary	71,634	76,300	77,300 e/	80,000 r/ e/	100,000
Secondary	30,000 e/	22,486	25,750	30,000 r/ e/	25,000
Total	101,634	98,786	103,000 e/	110,000 r/ e/	125,000
Taiwan, secondary e/	12,000	10,000	10,000	8,000	6,000
Turkey, primary	104,000	92,400	82,700	98,500 e/	120,000
United Kingdom:					
Primary	10,363	10,629	11,078	28,000 r/ e/	12,869 3/
Secondary	31,704	35,949	35,586	50,500 r/ e/	43,746 3/
Total	42,067	46,578	46,664	78,500 r/ e/	56,615 3/
United States:					
Primary:					
Electrowon	502,000	491,000	493,000	539,000	574,000 3/
Other	1,210,000	1,300,000	1,350,000	1,390,000	1,440,000 3/
Secondary	433,000	460,000	392,000	352,000	327,000 3/
Total	2,140,000	2,250,000	2,230,000	2,280,000	2,340,000 3/
Uzbekistan: e/					
Primary	70,000	55,000 r/	85,000 r/	75,000 r/	75,000
Secondary	10,000	10,000	5,000	5,000	5,000
Total	80,000	65,000 r/	90,000 r/	80,000 r/	80,000
Zaire, primary 9/	47,503	34,100 r/	29,000	33,000 r/	28,000

See footnotes at end of table.

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TABLE 22--Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Zambia, primary: 10/					
Electrowon	43,712	48,845	67,300	45,700 r/	54,600
Other	428,495	363,247	284,800	275,600 r/	270,000
Total	472,207	412,092	352,100	321,300 r/	325,000
Zimbabwe: 11/					
Electrowon	--	--	--	200	3,200
Primary	9,673	8,187	9,350	12,000 r/ e/	12,000
Secondary e/	8,200	8,200	6,000	6,000	6,000
Total e/	17,900	16,400	15,400	18,200 r/	21,200
Total, primary	8,980,000 r/	9,190,000 r/	9,090,000 r/	9,410,000 r/	10,200,000
Total, secondary	1,840,000 r/	1,770,000 r/	1,710,000 r/	2,110,000 r/	2,010,000
Total, primary and secondary, undifferentiated	349,000 r/	379,000 r/	379,000 r/	383,000 r/	379,000
Grand total	11,200,000	11,300,000 r/	11,200,000	11,900,000 r/	12,500,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. Table includes data available through July 10, 1997.

3/ Reported figure.

4/ Includes leach cathode from Zaire, which is processed.

5/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

6/ Dissolved Dec. 31, 1992.

7/ Data are for Iranian years beginning Mar. 21 of that stated.

8/ May include secondary.

9/ Excludes leach cathode exported for processing in Belgium.

10/ Data are for fiscal year beginning Apr. 1 of that stated. Electrowon covers only presumably high-grade electrowon cathodes reported as "finished production leach cathodes." Other, in addition to electrowon cathodes, includes a smaller amount of "finished product shapes" presumably cast from electrorefined cathodes, or any blister-anodes and low-anodes and low-grade electrowon cathodes that were furnace- or fire-refined.

11/ May include copper-nickel matte (copper content more than 6,000 tons per year) imported from Botswana for toll refining.

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INDUSTRIAL DIAMOND

By Ronald F. Balazik

In addition to its value as a gemstone, diamond has unique properties that make it ideal for many industrial and research applications. In fact, as the hardest substance known, diamond has been used for many centuries as a grinding, drilling, cutting, and polishing tool (Spear and Dismuks, 1994). Today, industrial-grade diamond (defined as diamond that does not meet gem-quality standards) continues to be used principally as an abrasive. Moreover, diamond has exceptional optical properties and superior electrical/thermal characteristics that make it the best material for special lenses, heat sinks in electrical circuits, wire drawing, and many advanced technologies.

Although both synthetic and natural diamonds are used by industry, synthetic industrial diamond is superior to its natural diamond counterpart in many cases because its properties can be tailored for specific applications. Thus, manufactured diamond accounts for at least 90% of the industrial diamond used in the United States.

Legislation and Government Programs

The National Defense Stockpile (NDS), operated by the Department of Defense (DOD), contained the following categories of industrial diamond in 1996: industrial stones, crushing bort, and diamond dies. At yearend, the NDS had an inventory of 4.65 million carats of industrial stones (valued at $78.3 million), 816,000 carats of crushing bort ($4.5 million), and 25,500 pieces of diamond dies ($917,000). Additional information on the value of NDS diamond is in the "Price" section that follows.

Congress has authorized the DOD to dispose of all NDS industrial diamond. For fiscal year 1997 (October 1, 1996, to September 30, 1997), the DOD has been authorized to sell up to 2 million carats of industrial stone and all stockpiled industrial bort and diamond dies.

Production

The U.S. Geological Survey (USGS) conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 1996 survey, a few significant firms withheld certain data that they deemed proprietary. Thus, only estimates of U.S. primary and secondary output are provided below.

As one of the world's leading producers of synthetic industrial diamond in 1996, the United States accounted for an estimated output of 114 million carats. Only two U.S. companies produced synthetic industrial diamond during the year: Du Pont Industrial Diamond Division, Gibbstown, NJ; and GE Superabrasives, Worthington, OH. In addition, GE Superabrasives and five other firms (Dennis Tool Co., Houston, TX; Phoenix Crystal, Ann Arbor, MI; SII Megadiamond Industries Inc., Provo, UT; Tempo Technology Corp., Somerset, NJ; and U.S. Synthetic Corp., Orem, UT) manufactured polycrystalline diamond (PCD) from synthetic diamond grit.

More than 20 million carats of industrial diamond were estimated to have been recycled in the United States during 1996. Most of this material was recovered from residues generated in the manufacture of PCD (Wilson Born, National Research Company, written commun., 1997). Four U.S. companies recovered and sold industrial diamond as their principal product in 1996. These firms were: Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston, TX; and National Research Company, Fraser, MI. These firms reclaimed industrial diamond from used drill bits, diamond tools, and diamond-containing wastes as well as from the residues of PCD manufacturing. In addition to these companies, other domestic firms reportedly recovered industrial diamond in smaller secondary operations.

A new diamond mine under development near Fort Collins, Colorado, may prove to be the first significant domestic source of natural industrial diamond in the United States. The mine would be the first commercial diamond mine in North America in almost a century (U.S. Geological Survey, 1997). A diamond processing plant at the mine began operating in May 1996. By yearend, about 65% of the recovered diamonds were gem quality; presumably, the remainder can be used for industrial purposes.

Consumption

The United States remained the world's largest market for industrial diamond in 1996. Domestic consumption of industrial diamond during the year was estimated to be 224 million carats. This consumption reflects growth in the U.S. economy and the many domestic industries where diamond is used. Domestic consumption in the 1990's was accounted for primarily by the following U.S. industry sectors: construction, machinery manufacturing, mineral services, stone and ceramics production, and transportation equipment fabrication.

Industrial diamond stones (usually larger than 800 microns) are used primarily in drilling bits and reaming shells, single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire-drawing dies. Miscellaneous uses include:

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engraving points, glass cutters, bearings, and surgical instruments. Diamond drilling bits and shells are used principally for mineral, oil, and gas exploration. Other applications for diamond bits and shells include foundation testing, masonry drilling, and inspecting concrete in various structures. The primary uses of point diamond tools are for dressing and truing grinding wheels and for cutting, machining, boring, and finishing; beveling glass for automobile windows also is an application. Cutting dimension stone and concrete in highway reconditioning are the major uses of diamond saws; another application is the forming of refractory shapes for furnace linings. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys.

Diamond grit, powder, and fragmented bort are used in diamond grinding wheels, saws, impregnated bits and tools, and loose abrasives compounds for lapping and polishing. Three major types of grinding wheels are made: resinoid, metal, and vitrified bonds. These tools are made in many shapes and sizes designed for specific applications. Very large grinding wheels can be as much as 1 meter in diameter. The primary uses of diamond grinding wheels include the sharpening and shaping of carbide machine tool tips, die grinding, plate glass edging, and optical grinding. Saws made with diamond grit are used to cut concrete, stone, ceramics, and composite materials. Very fine saws are used to slice brittle metals and crystals into thin wafers for electronic and electric devices.

Polishing and lapping powder and compounds are used primarily to finish optical surfaces, jewel bearings, gemstones, wiredrawing dies, cutting tools, and metallographic specimens. Hundreds of other important items made from metals, ceramics, plastics, and glass also are finished with diamond compounds.

Changes in technology have resulted in an increased use of synthetic industrial diamond and polycrystalline diamond shapes (PDS) and compacts (PDC) for many of the applications cited above. In particular, the use of PDS, PDC, and matrix set synthetic diamond grit for drilling bits and reaming shells has increased in recent years. Moreover, PDS and PDC are used in the manufacture of single- and multiple-point tools, and PDC is used in a majority of the diamond wire-drawing dies. The manufacturing PCD for PDS and PDC now accounts for most of the diamond powder consumed in the United States (Wilson Born, National Research Company, written commun., 1997).

Prices

Although the USGS does not collect industrial diamond price data, it monitors the average value of certain industrial diamond imports. In 1996, average per-carat values for U.S. imports of natural grit and powder, synthetic grit and powder, and industrial stones were $0.42, $0.45, and $7.54, respectively. These values are slightly higher than those of 1995.

In addition, at yearend 1996, the DOD appraised the average per-carat market value of crushing bort and industrial stones in the NDS at $5.51 and $16.84, respectively. In certain cases, however, significantly higher assessments of industrial diamond in the stockpile have been made; for example, some bidders at NDS disposal sales have paid almost $100 per carat for stockpiled diamonds that they valued as gem-quality stones.

Events in 1996, such as new diamond mines (for example, see the preceding "Production" section) and more suppliers in the rough diamond market, may dampen prices of natural industrial stone during the next few years.

Foreign Trade

The United States is the world's leading importer and exporter of industrial diamond; in 1996, imports came from more than 30 countries, and exports/reexports went to at least 50 countries. Although the United States is a major producer of synthetic diamond, its growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. Moreover, U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations because domestic production of natural diamond was lacking. The new Colorado diamond mine noted on page 1, however, may help to reduce this reliance on foreign sources.

In 1996, domestic imports of diamond powder, dust, and grit reached a record high of 218 million carats (valued at $99 million). Imports of industrial quality stones were 2.9 million carats (valued at $22 million). China appears to be growing as a major source of synthetic diamond for U.S. markets. *(See tables 1 and 2.)*

During 1996, the United States also exported and reexported 108 million carats of industrial diamond dust, powder, and grit (valued at $94 million). Additionally, the United States exported and reexported about 3.3 million carats of industrial stones (valued at $27 million). *(See tables 3 and 4.)*

World Review

The global market for industrial diamond was estimated to be more than $650 million in 1996. The United States remained the world's largest single market for industrial diamond as its economy continued to expand.

More than 35 countries produced industrial diamond in 1996. Almost two-thirds of global output, however, was accounted for by just the top four producers: The United States, Russia, Ireland, and South Africa. Synthetic diamond accounts for about 90% of global production and consumption. Tables 5 and 6 show world production of natural and synthetic industrial diamond by country.

Outlook

The United States will continue to be the world's largest market for industrial diamond well into the 21st century, and will remain a significant exporter of industrial diamond as well. Polycrystalline diamond for abrasive tools and wear parts will continue to replace competing materials in many industrial applications by extending tool life, providing closer tolerances, and yielding lower parts cost (Thomas Corcoran, ANCO

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Industrial Diamond Corp., written commun., 1997).

Demand for diamond grit and powder worldwide, particularly in the United States, will exhibit significant growth during the next several years. Demand for synthetic grit and powder is expected to be greater than that for natural diamond stone. Constant-dollar prices of synthetic diamond products probably will continue to decline as production technology becomes more cost-effective and competition from low-cost producers in China and Russia increases. The consolidation of major synthetic diamond producers, however, could stabilize prices in saw-grade sizes.

The most dramatic increase in the use of diamond tools made from synthetic grit and powder will likely be in the construction industry. Large quantities of saw-grade diamond will be required for the repair and replacement of highways and bridges. Additionally, the dimension stone industry will increase its demand for diamond as a cutting and polishing medium. The use of diamond tools for cutting, shaping, and polishing will increase in the glass industry as well. Moreover, PDC and PDS will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries (Wilson Born, National Research Company, written commun., 1997).

Truing and dressing applications will be the major domestic end-use for industrial stones during the next several years. These stones are natural and cannot be manufactured commercially. No shortage of the stones is anticipated, however, because new mines (in Canada and the United States, for example) and more producers selling in the rough diamond market will maintain ample supplies (Thomas Corcoran, ANCO Industrial Diamond Corp., written commun., 1997). These additional sources will tend to reduce prices as well.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Natural industrial diamond stones (including glazers' and engraver's diamond unset) (7102.21.3000 and .4000)				Miners' diamond, natural and synthetic (7102.21.1010 and .1020)			
	1995		1996		1995		1996	
Country	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Belgium	224	798	206	1,200	571	3,630	276	735
China	91	176	47	80	2	2	(3/)	10
Ghana	103	445	181	1,000	36	300	87	577
India	5	4	7	119	--	--	(3/)	2
Ireland	88	168	133	289	1	17	6	20
Japan	1	4	(3/)	17	(3/)	19	--	--
Netherlands	18	956	5	1,430	2	67	(3/)	9
Sierra Leone	18	116	49	633	18	65	4	16
South Africa	90	150	(3/)	16	4	54	(3/)	85
Switzerland	1	3	6	20	140	341	201	417
United Kingdom	858	6,880	402	3,520	654	8,810	495	6,990
Zaire	663	954	354	796	37	1,910	101	1,710
Other	450 r/	1,050 r/	288	1,200	29 r/	257 r/	10	655
Total	2,610	11,700	1,680	10,300	1,490	15,500	1,180	11,200

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND POWDER, DUST AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

	Diamond powder and dust							
	Synthetic (7105.10.0020; .0030 and .0050)				Natural (7105.10.0011 and .0015)			
	1995		1996		1995		1996	
Country	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Austria	1,290	1,460	288	312	15	3	148	203
Belgium	2,050	3,040	3,100	4,210	2,180	1,930	1,790	2,130
China	7,240	1,740	23,800	5,150	11,200	1,440	7,320	994
Germany	11,400	4,300	7,920	1,850	69	86	24	19
Hong Kong	489	88	4,440	797	844	176	1,950	401
India	163	160	54	41	48	33	209	100
Ireland	116,000	48,200	112,000	61,400	2,440	2,040	2,390	1,300
Japan	3,800	2,350	4,240	2,240	--	--	2	6
Korea, Republic of	6,750	6,650	25,000	9,290	1,250	899	876	636
Russia	9,860	1,690	9,930	2,100	35	53	1,070	210
South Africa	104	52	--	--	--	--	1	8
Switzerland	985	673	1,340	946	293	341	332	195
Ukraine	2,710	521	1,640	170	--	--	--	--
United Kingdom	3,420	1,750	5,500	1,970	1,300	674	433	333
Other	1,140 r/	724 r/	2,050	1,040	803 r/	379 r/	839	846
Total	167,000	73,400	201,000	91,500	20,500	8,050	17,400	7,370

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

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TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY 1/

(Thousand carats and thousand dollars)

Country	Industrial unworked diamonds (7102.21.0000)			
	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Belgium	3,440	17,000	1,650	14,500
Brazil	11	27	16	120
Canada	512	1,410	328	1,120
Germany	110	899	50	394
Hong Kong	194	1,370	55	572
India	14	105	--	--
Ireland	22	210	73	325
Israel	144	1,440	53	397
Italy	--	--	17	39
Japan	512	5,220	768	6,880
Korea, Republic of	98	946	106	976
Netherlands	36	364	25	246
Netherlands Antilles	12	120	1	7
Switzerland	15	152	16	163
United Kingdom	41	347	43	416
Other	22	264	57	417
Total	5,180	29,900	3,260	26,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

TABLE 4
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST AND GRIT, BY COUNTRY 1/

(Thousand carats and thousand dollars)

Country	Diamond powder and dust							
	Synthetic (7105.10.0025)				Natural (7105.10.1010)			
	1995		1996		1995		1996	
	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/	Quantity	Value 2/
Australia	725	1,950	625	1,290	80	122	34	69
Austria	1,450	869	1,260	962	267	201	194	72
Belgium	1,420	650	2,180	2,070	175	208	327	260
Brazil	1,570	1,090	1,480	1,010	7	12	96	79
Canada	2,830	6,220	2,990	6,280	10	10	49	112
China	612	597	1,280	497	--	--	--	--
France	532	299	232	184	24	29	16	25
Germany	27,800	26,600	17,300	19,300	264	228	279	233
Hong Kong	6,440	3,330	7,700	3,620	17	58	163	139
India	2,180	1,700	4,130	2,310	6	14	--	--
Ireland	9,030	9,890	10,800	13,200	544	1,280	214	412
Israel	1,260	371	290	130	111	93	219	53
Italy	1,310	1,090	999	607	315	223	84	87
Japan	18,100	18,600	25,000	20,900	129	135	334	324
Korea, Republic of	10,100	8,060	12,300	9,000	95	130	143	268
Luxembourg	290	475	115	73	102	214	170	198
Mexico	127	190	193	131	29	46	169	145
Singapore	525	708	1,460	1,020	265	663	147	161
South Africa	--	--	15	34	110	221	--	--
Switzerland	2,220	946	2,100	988	203	213	221	197
Taiwan	2,480	1,700	3,940	2,570	173	434	218	108
Thailand	1,190	885	450	376	5	11	12	34
United Kingdom	3,870	4,940	3,240	1,960	989	848	1,410	1,080
Other	1,350	1,300	3,160	1,670	187	359	91	57
Total	97,300	92,400	103,000	90,200	4,110	5,750	4,590	4,110

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

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TABLE 5
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1992	1993	1994	1995	1996
Gemstones: 3/					
Angola 4/	1,100	130	270	2,700 r/	3,600
Australia	18,100	18,800	19,500	18,300	18,897 5/
Botswana	11,200	10,300	10,550 5/	11,500	11,000
Brazil	653	1,000 r/	300 r/	700 r/	700
Central African Republic	307 5/	370	400	400	350
China	200	230	230	230	230
Gabon	400	400	400	400	400
Ghana	104 r/ 5/	106 r/ 5/	118 r/	126 r/	125
Nambia	1,520	1,120	1,312 5/	1,382 5/	1,300
Russia	9,000	8,000	8,500	9,000	9,250
Sierra Leone	180	90	155	113 5/	162
South Africa	4,600	4,600	5,050 r/	5,070 r/	5,360
Venezuela	302	145 r/ 5/	203	229 5/	230
Zaire	8,930	2,010	4,000	4,000	3,000
Other	305	277 r/	463 r/	608 r/	813
Total	56,800 r/	47,600 r/	51,400	54,800 r/	55,400
Industrial:					
Angola 4/	80	15	30	300 r/	400
Australia	22,100	23,000	23,800	22,400	23,096 5/
Botswana	4,790	4,420	5,000	5,300	5,000
Brazil	665	600 r/	600 r/	600 r/	600
Central African Republic	107 5/	125	131	130	120
China	800	850	850	900	900
Gabon	100	100	100	100	100
Ghana	590 r/ 5/	484 r/ 5/	473 r/ 5/	505 r/	505
Nambia	30	20	--	--	--
Russia	9,000	8,000	8,500	9,000	9,250
Sierra Leone	116	68	100	101 r/	108
South Africa	5,600	5,700	5,800 r/	5,880 r/	6,000
Venezuela	176	155 5/	214 5/	64 5/	60
Zaire	4,570	13,600	13,000	13,000	15,000
Other	218	210 r/	277 r/	344 r/	464
Total	48,900 r/	57,400	58,900 r/	58,600 r/	61,600
Grand total	106,000	105,000	110,000	113,000 r/	117,000

r/ Revised.
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through May 28, 1997.
3/ Includes near-gem and cheap-gem qualities.
4/ Figures do not include smuggled artisanal production.
5/ Reported figure.

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TABLE 6
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand carats)

Country	1992	1993	1994	1995	1996
Belarus	30,000 3/	30,000 3/	25,000	25,000	25,000
China	15,000	15,500	15,500	15,500	15,500
Czech Republic 4/	XX	5,000	5,000	5,000	5,000
Czechoslovakia 5/	10,000	XX	XX	XX	XX
France	3,500	3,500	3,500	3,000	3,000
Greece	750	1,000	1,000	1,000	750
Ireland	60,000	65,000	65,000	60,000	60,000
Japan	30,000	32,000	32,000	32,000	32,000
Poland	320	98	271	256	250
Romania	3,000	5,000	5,000	5,000	5,000
Russia	80,000	80,000	80,000	80,000	80,000
Serbia and Montenegro	-- r/	-- r/	-- r/	-- r/	--
Slovakia 4/	XX	5,000	5,000	5,000	5,000
South Africa	60,000 3/	60,000 3/	60,000	60,000	60,000
Sweden	25,000	25,000	25,000	25,000	25,000
Ukraine	10,000 3/	10,000 3/	8,000	8,000	8,000
United States	90,000	103,000	104,000	115,000	114,000
Total	418,000 r/	440,000 r/	434,000 r/	440,000 r/	439,000

r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 28, 1997.

3/ Reported figure.

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Dissolved Dec. 31, 1992.

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DIATOMITE

By Jim F. Lemons, Jr.

Diatomite, or diatomaceous earth, is a sedimentary rock composed of the fossilized skeletal remains of diatoms, one-celled algae-like plants ranging in size typically from 10 to 200 microns. In commercial applications, the silica content (SiO_2) is usually over 86% and may be as high as 94%, and the skeletal structure can contain up to 80% to 90% voids. Diatomite's porous structure, low density, and high surface area result in industrial applications as a filtration media for various beverages, inorganic and organic chemicals, and as an absorbent for pet litter and oil spills.

Production

For the United States, the diatomite production data shown in table 1 were collected by a voluntary survey of producers with 100% response. These surveys cover the 6 diatomite producers with 12 facilities in California, Nevada, Oregon, and Washington. Major producers were Celite Corp. (Lompoc, CA and Quincy, WA); Grefco Minerals, Inc. (Burney and Lompoc, CA); Moltan Company (Fernley, NV); and Eagle-Picher Industries Inc. (Lovelock and Fernly, NV and Vale, OR). California continued to be the lead producing State. The deposits at Lompoc, CA are marine, all other U.S. production is from lake-formed deposits. Recovery of diatomite from these deposits is by open pit mining using different combinations of dozers, scrapers, and front-end loaders. Diatomite processing typically involves a series of crushing, drying, and calcining operations to remove organic contaminants.

The United States is the world's largest producer and consumer of diatomite. U.S. production in 1996 remained steady at 698,000 metric tons valued at $176 million f.o.b. plant, comparable with 1995 production levels of 687,000 tons valued at $171 million.

Consumption

Apparent domestic consumption of processed diatomite in 1996 was 557,000 tons comparable with 1995 consumption of 544,000 tons. The principal products are various grades of straight-calcined or flux-calcined powders, plus minor amounts of uncalcined product. The principal use of diatomite is in filtration of various alcoholic beverages, sugar, vegetable and animal fats, organic and inorganic chemicals, water, and pharmaceutical and biotechnological media. (*See table 2.*) In 1996, domestic and export sales of filter-grade diatomite were 470,000 tons, 3% less than in 1995.

Sales of diatomite as a absorbent, the second largest use, were 98,000 tons. Pet litter and oil spill absorbents are the primary markets. Filler use accounted for 90,000 tons, 18% more than in 1995. Diatomite applications include pesticide carrier; catalyst carrier; roughness and flatting agent in paint and polishes; an antiblocking agent in polyethylene film; a soft abrasive in silver and automotive polishes; bulk extender; and thermal insulator.

Prices

The estimated average unit value of U.S. diatomite, f.o.b. plant was $252 per metric ton in 1996 compared with $249 ton in 1995.(*See table 3.*) The average value per ton for the major end uses in 1996 were $268 for filtration and $293 for fillers.

Foreign Trade

In 1996, the United States exported 143,000 tons, approximately 20% of domestic production, to 77 countries. (*See table 4.*) Main export markets were Canada (23,000 tons) and Germany (18,000 tons). Other major markets included France (12,000 tons), Japan (11,000 tons), and the United Kingdom (9,000 tons). The average unit value of exported diatomite was $294 per metric ton, comparable with 1995 values of $301 per ton. Imports of diatomite were 1,550 tons, of which 95% was supplied by France.

World Review

World production remained steady with 1995 values of 1.4 million tons. (*See table 5.*) Major producers were the United States, distantly followed by France and the Republic of Korea. These countries accounted for 61% of world production. Denmark accounted for 7% of world production and remained the only source of moler and impure diatomite containing up to 30% clay. Moler is used in insulation materials, especially bricks for kiln and furnace applications. It is also used in industrial applications as an absorbent, filter, and bulk extender. The countries that made up the former Soviet Union together account for 7% of world production.

Outlook

Diatomite is losing market share to other filtration technologies that utilize ceramic, polymeric or carbon membrane filters. However, its use as an absorbent is growing. These two markets, one rising, the other decreasing indicate only a slow overall growth for the industry.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
DIATOMITE SOLD OR USED, 1/ BY MAJOR USE

(Thousand metric tons)

		1995	1996
Domestic production (sales)		687	698
Value	thousands	$171,000	$176,000

1/ Data are rounded to three significant digits.

TABLE 2
DIATOMITE SOLD OR USED, 1/ BY MAJOR USE

(Percent of U.S. production)

Major use	1995	1996
Absorbents	13	14
Fillers	11	13
Filtration	70	67
Insulation	3	3
Other 2/	3	3

1/ Includes exports.
2/ Includes additives and silicate admixtures.

TABLE 3
AVERAGE ANNUAL VALUE PER METRIC TON 1/
OF DIATOMITE, BY MAJOR USE

Major use	1995	1996
Fillers	$302.29	$292.56
Filtration	269.75	268.42
Insulation	113.77	115.72
Other 2/	146.48	180.86
Weighted average	249.48	252.10

1/ Based on unrounded data.
2/ Includes absorbents, additives, and silicate admixtures.

TABLE 4
U.S. EXPORTS OF DIATOMITE 1/

(Thousand metric tons and thousand dollars)

Year	Quantity	Value 2/
1995	144	43,300
1996	143	42,000

1/ Data are rounded to three significant digits.
2/ U.S. customs value.

Source: Bureau of the Census.

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TABLE 5
DIATOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria	4	3	4 e/	4 e/	4
Argentina	5	3	6 r/	5 r/	5
Australia e/	11	11	11	11	11
Brazil (marketable)	15	16	17 r/	14 r/	14
Canada e/ 3/	10	10	10	10 r/	10
Chile	6	6	10	10 e/	10
Colombia e/	4 4/	4	4	4	4
Costa Rica e/	12	12	12	12	12
Denmark: e/ 5/					
Diatomite	1	1	1	1	1
Moler	95	95	95	95	95
France e/	85	85	90	80 r/	85
Germany	52	52	52 e/	50 e/	50
Iceland	20	19 e/	25 r/	24 r/ e/	20
Iran 6/	(7/)	(7/)	(7/) e/	(7/) e/	(7/)
Italy e/	26	25	25	25	25
Kenya	1	1	1	1	1
Korea, Republic of	77	67	83	81 r/	80
Macedonia e/	5	5	5	5	5
Mexico	46	46	52 r/	55 r/	56
Peru e/	25	35 r/	35 r/	35 r/	35
Portugal	2	2	2	2 e/	2
Romania	15	10 r/	35 r/	48 r/	45
South Africa	1	--	--	--	--
Spain e/	36 4/	38	36	36	40
Thailand	10	8	6 r/	6 r/	6
U.S.S.R. e/ 8/	190	150	120	110	100
United Kingdom e/	(7/)	(7/) 4/	(7/)	-- r/	--
United States 9/	595	599	613	687 e/	698
Total	1,350	1,300	1,350 r/	1,410 r/	1,410

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 7, 1997.

3/ Includes an unknown quantity of fuller's earth.

4/ Reported figure.

5/ Data represent sales.

6/ Data are for Iranian years beginning Mar. 21 of that stated.

7/ Less than 1/2 unit.

8/ Dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries.

9/ Sold or used by producers.

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EXPLOSIVES

By Deborah A. Kramer

In 1996, total U.S. production of explosives of 2.24 million metric tons was slightly lower than that of 1995, and sales of explosives were recorded in all States except Delaware. Coal mining remained the dominant application for explosives, accounting for about two-thirds of total sales. Unusual factors that led to record coal production are expected to return to normal in the next 2 years, and explosives consumption for this application is expected to grow slowly or decline, depending on the replacement of production from the Eastern and Midwestern States by production from the Western States.

The 1995 Oklahoma City bombing continued to affect the explosives industry. Under a new law, taggants (materials used to trace explosives by manufacturer) for explosives were the subject of a study to determine if such materials could be used to identify the manufacturer.

Legislation and Government Programs

In the wake of the Oklahoma City bombing in April 1995, the President signed Public Law 104-132 on April 24, 1996. The law, the Antiterrorism and Effective Death Penalty Act of 1996, included a provision for the Secretary of the Treasury to conduct a study of methods for tagging explosives for detection and identification and of the feasibility of decreasing the reactivity of common chemicals that are used in the manufacture of explosives, such as ammonium nitrate fertilizers. The study was mandated to be completed within 1 year from the enactment of the law. Any portion of the study that affected the regulation or use of fertilizers as a preexplosive material was to be conducted in consultation with nonprofit fertilizer research centers. Black powder and smokeless powder were excluded from the study.

In August, the U.S. Department of the Treasury funded the National Research Council (NRC) to execute the taggant and fertilizer study called for in the new law. The NRC will evaluate several options for taggants, as well as estimate costs for adding the material to explosives. Some of the taggants that already are being used commercially are (1) multicolored, multilayer plastic particles; code is based on color sequence of particles, (2) rare-earth elements embedded in synthetic granules blended with fluorescent pigments and iron powder; code is based on matrix melting point and composition of embedded elements, (3) isotopically labeled trace components of material being tagged; code is based on extent of substitution and proportion of substituted compounds, (4) inert chemicals identifiable by specific antibodies; code is the chemical identity, (5) polymeric microbeads with differing diameters and colors; code is based on population of various sizes and colors, and (6) slow-release microcapsules containing perfluorodimethylcyclohexane or perfluoromethylcyclohexane to enhance detectability. In a cost estimate completed by Microtrace Inc. (not part of the NRC study), taggants for explosives were estimated to cost about $133 per pound. At a concentration of 250 parts per million, the taggant cost would add about 3 cents per pound to the cost of the explosive material (Rouhi, 1996). Taggant producers claim that these materials can be added to commercial explosives and fertilizers without interfering with chemical reactions; explosives industry analysts, however, claim that the cost is prohibitive for materials that are priced as bulk commodities and that the quantity of explosives used in criminal acts is small.

In July, a Federal district court judge dismissed the class-action lawsuit against ICI Explosives filed in 1995 on behalf of victims from the Oklahoma City bombing. ICI Explosives argued that no known additive could have been added to the fertilizer to prevent it from becoming explosive when mixed with the fuel oil (Fertilizer Markets, 1996).

The Mine Safety and Health Administration published a final rule for safety standards for explosives at metal and nonmetal mines. This final rule revises existing standards for separation of detonators from other explosives and blasting agents during storage and transport. It also revises existing standards for loading and blasting of explosive materials and protection of explosives from impact and exposure to high temperatures (U.S. Department of Labor, 1996).

Production

Ammonium-nitrate base explosives (blasting agents and oxidizers) sales were 2.20 million tons, a decline of about 4% from that of 1995. Ammonium-nitrate base explosives accounted for 98% of U.S. industrial explosives sales. Sales of permissibles and other high explosives also declined; these sales dropped by 14%. Ten-year supply trends are shown in figure 1. *(See table 1 and figure 1.)*

Companies covered by this report, including those not members of the Institute of Makers of Explosives (IME), denoted by an asterisk, are as follows:

Accurate Energetic Systems
Apache Nitrogen Products Inc. *
Austin Powder Co.
Coastal Chem Inc. *
Amos L. Dolby Co.
Douglas Explosives Inc.
Dyno Nobel Inc.

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El Dorado Chemical Co.
The Ensign-Bickford Co.
Explosives Technologies International Inc. (ETI)
Goex International Inc.
D.C. Guelich Explosives Co.
Halliburton Energy Services
HITECH Inc.
ICI Explosives Canada
ICI Explosives USA Inc.
LaRoche Industries Inc.
Maynes Explosives Co.
Mining Services International
W.A. Murphy Inc.
Nitram Inc. *
Nelson Brothers
Nitrochem Inc.
Owen Oil Tools Inc.
St. Lawrence Explosives Corp.
Schlumberger Perforating Center
SENEX Explosives Inc.
Sierra Chemical Co.
Slurry Explosives Corp.
Unocal Corp. *
Viking Explosives and Supply Co.
Western Atlas International

In November, Potash Corp. of Saskatchewan (PCS) announced that it would acquire Arcadian Corp. through an exchange of stock; Arcadian stock would be converted to PCS stock. The acquisition would include Arcadian's explosives-grade ammonium nitrate facilities in Memphis, TN, as well as its agricultural-grade ammonium nitrate facilities. A vote to approve the acquisition was expected to be held in January 1997 (Green Markets, 1996).

Consumption

Coal mining, with 65% of total explosives consumption, remained the largest application for explosives in the United States. According to the U.S. Department of Energy (DOE), the U.S. coal industry produced the largest quantity of coal ever in 1996, 959 million tons, a 2.3% increase from 1995 production. The electric power industry consumed record quantities of coal. Strong economic growth, colder-than-normal weather in the early part of the year, and high natural gas prices contributed to this record coal usage. Interfuel competition for the electricity generation market was the principal reason for a shift in regional coal production patterns. For the past several years, production of low-sulfur coal from the Western States was increasing at a greater rate than that of high- and medium-sulfur coal from the Eastern States. In 1996, coal output in the Appalachian and interior regions increased. Wyoming, West Virginia, and Kentucky, in descending order, led the Nation in coal production, accounting for 56% of the total (Hong, 1997). Kentucky, West Virginia, and Wyoming, in descending order, also were the three largest explosives-consuming States, accounting for 35% of total U.S. explosives sales. Ten-year consumption trends, by industry, are shown in figure 2. *(See figure 2.)*

Quarrying and nonmetal mining, with 14% of total explosives sales, was the second-largest consuming industry; metal mining accounted for 11% of sales, construction accounted for 7%, and miscellaneous uses accounted for 3%. Kentucky, West Virginia, Wyoming, Virginia, and Pennsylvania, in descending order, were the largest consuming States, with a combined total of 48% of U.S. sales. *(See tables 2 and 3.)*

According to Bureau of the Census statistics, the value of new construction increased by 1.9%, based on constant 1992 dollars (U.S. Department of Commerce, 1997). Federal Reserve Board indexes indicate that the industry growth rate for metal mining from 1995 to 1996 was 0.1% and that the growth rate for stone and earth minerals was 5.6% (Federal Reserve Board, 1997).

Classification of Industrial Explosives and Blasting Agents.—Apparent consumption of commercial explosives used for industrial purposes in this report is defined as sales as reported to the IME. Commercial explosives imported for industrial uses were included in sales.

The principal distinction between high explosives and blasting agents is their sensitivity to initiation. High explosives are cap-sensitive, whereas blasting agents are not. Black powder sales were minor and were last reported in 1971.

The production classifications used in this report are those adopted by the IME.

High Explosives.—Permissibles.—Grades approved by brand name by the Mine Safety and Health Administration, as established by U.S. Bureau of Mines testing.

Other High Explosives.—All high explosives except permissibles.

Blasting Agents and Oxidizers.—Includes (1) ammonium nitrate-fuel oil (ANFO) mixtures, regardless of density; (2) slurries, water gels, or emulsions; (3) ANFO blends containing slurries, water gels, or emulsions; and (4) ammonium nitrate in prilled, grained, or liquor (water solution) form. Bulk and packaged forms of these materials are contained in this category. In 1996, about 85% of the total blasting agents and oxidizers was in bulk form.

World Review

Two new explosives-grade ammonium nitrate plants are being planned for Chile. ICI Explosives of the United Kingdom completed a feasibility study for a 220,000-ton-per-year ammonium nitrate plant near Santiago. The $40 million project has a projected startup date of the first quarter of 1998 (European Chemical News, 1996). The Chilean explosives producer Enaex was planning a 250,000-ton-per-year ammonium nitrate plant at its complex in Mejillones in northern Chile. Ammonia for the ammonium nitrate plant will be supplied by a new 120,000-ton-per-year facility being

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constructed in conjunction with the State oil corporation. Total cost of the project is estimated to be $180 million. No startup date for the project was announced (Fertilizer International, 1996).

Kemira Group announced that it would sell 50.1% of its Vihtavuori subsidiary to the Finnish Government in 1997; this would effectively end the company's involvement with explosives and ammunition. The Government, which already owns 72% of Kemira, plans to acquire the explosives portion of the business for strategic reasons (Chemical Marketing Reporter, 1996).

Outlook

According to the DOE, coal production is expected to grow by 2.6% in 1997 and by an additional 3.0% in 1998. Production in the western region should continue to rise significantly over the forecast period, while production in the interior region declines and Appalachian region production grows slowly. In 1997, demand for electricity is expected to grow more slowly, at 1.0%, than it did in 1996. This is due mainly to the mild winter weather offsetting the effects of economic growth. In 1998, demand is expected to rise by 2.7% as the weather returns to more normal patterns and as the economy continues to grow (U.S. Department of Energy, 1997).

Consumption of explosives, however, is not expected to grow at the same annual rate as that of coal production. Because the largest production increase is expected in the western region, which generally has a lower overburden-to-matrix ratio, explosives consumption is expected to grow at a slower rate than overall coal production and may possibly decline if enough production in the Appalachian and interior regions is replaced by production from the western region. Natural gas prices are expected to stabilize, so interfuel competition will most likely be eliminated, and production of high-sulfur coal will decrease from the high level in 1996.

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TABLE 1
SALIENT STATISTICS OF INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES 1/

(Metric tons)

Class	1995	1996
Permissibles	3,420	2,510
Other high explosives	36,400	31,800
Blasting agents and oxidizers	2,240,000	2,200,000
Total	2,280,000	2,240,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Institute of Makers of Explosives.

TABLE 2
INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY CLASS AND USE e/ 1/ 2/

(Thousand metric tons)

Class	Coal mining	Quarrying and nonmetal mining	Metal mining	Construction work	All other purposes	Total
1995:						
Permissibles	3	(3/)	--	(3/)	--	3
Other high explosives	4	16	2	13	1	36
Blasting agents and oxidizers	1,490	292	248	152	66	2,240
Total	1,490 r/	308	250	165	68	2,280
1996:						
Permissibles	3	(3/)	--	(3/)	--	3
Other high explosives	4	15	1	10	2	32
Blasting agents and oxidizers	1,460	295	238	150	63	2,200
Total	1,460	310	239	160	64	2,240

e/ Estimated. r/ Revised.
1/ Distribution of industrial explosives and blasting agents by consuming industry in 1995-96 estimated from indices of industrial production and economies as reported by the U.S. Department of Energy, the Federal Reserve Board, the U.S. Department of Transportation, and the Bureau of the Census.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

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TABLE 3
INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY STATE AND CLASS, 1996 1/

(Metric tons)

State	Class			
	Fixed high explosives			
	Permissibles	Other high explosives	Blasting agents and oxidizers	Total
Alabama	118	625	71,700	72,500
Alaska	--	1,010	8,770	9,780
Arizona	--	532	126,000	127,000
Arkansas	1	282	10,100	10,400
California	--	723	45,000	45,700
Colorado	--	397	7,340	7,740
Connecticut	--	657	6,390	7,050
Florida	--	223	31,600	31,800
Georgia	--	744	24,300	25,100
Hawaii	--	--	1,230	1,230
Idaho	1	664	12,600	13,200
Illinois	5	729	40,000	40,700
Indiana	1	527	126,000	127,000
Iowa	--	864	10,800	11,600
Kansas	--	523	16,000	16,600
Kentucky	1,170	2,390	352,000	356,000
Louisiana	--	277	2,230	2,500
Maine	--	53	486	539
Maryland 2/	--	168	5,010	5,180
Massachusetts	--	712	2,900	3,620
Michigan	--	162	28,000	28,200
Minnesota	--	234	44,200	44,400
Mississippi	--	83	73	157
Missouri	1	2,570	32,300	34,800
Montana	--	1,280	16,400	17,600
Nebraska	--	81	774	855
Nevada	23	1,760	71,600	73,400
New Hampshire	--	770	1,860	2,630
New Jersey	--	181	3,100	3,280
New Mexico	--	455	85,000	85,400
New York	--	615	12,000	12,600
North Carolina	--	748	25,500	26,300
North Dakota	--	119	2,960	3,080
Ohio	13	696	74,900	75,600
Oklahoma	2	323	22,700	23,000
Oregon	--	615	8,000	8,620
Pennsylvania	242	2,130	139,000	142,000
Rhode Island	--	2	92	93
South Carolina	--	109	4,920	5,030
South Dakota	--	74	7,830	7,910
Tennessee	33	1,610	30,800	32,400
Texas	(3/)	782	40,600	41,400
Utah	461	384	44,800	45,600
Vermont	3	124	394	521
Virginia	291	1,130	146,000	148,000
Washington	103	644	13,200	14,000
West Virginia	40	1,090	242,000	243,000
Wisconsin	--	592	14,300	14,900
Wyoming	--	342	189,000	189,000
Total	2,510	31,800	2,200,000	2,240,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes the District of Columbia.
3/ Less than 1/2 unit.

Source: Institute of Makers of Explosives.

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FIGURE 1
SUPPLY TREND FOR U.S. INDUSTRIAL EXPLOSIVES

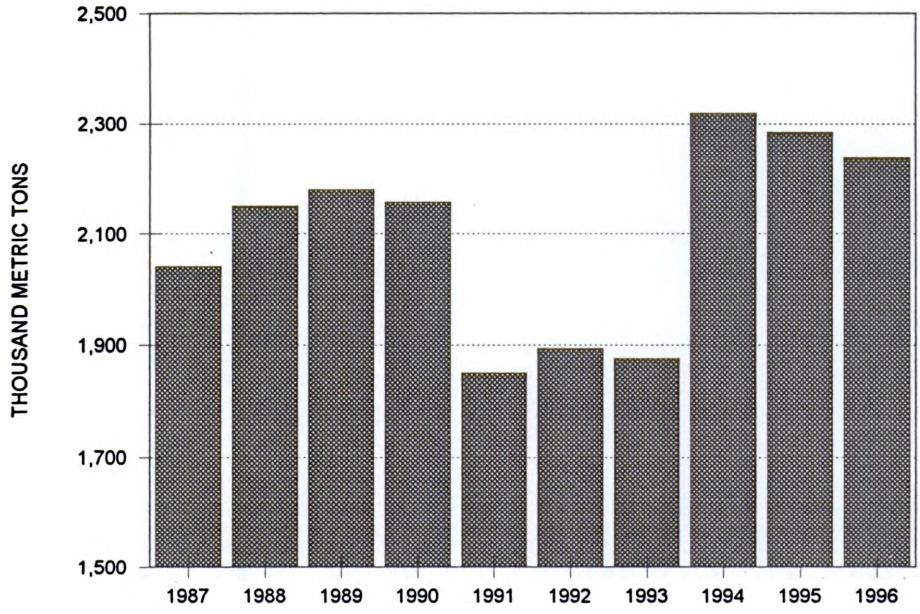
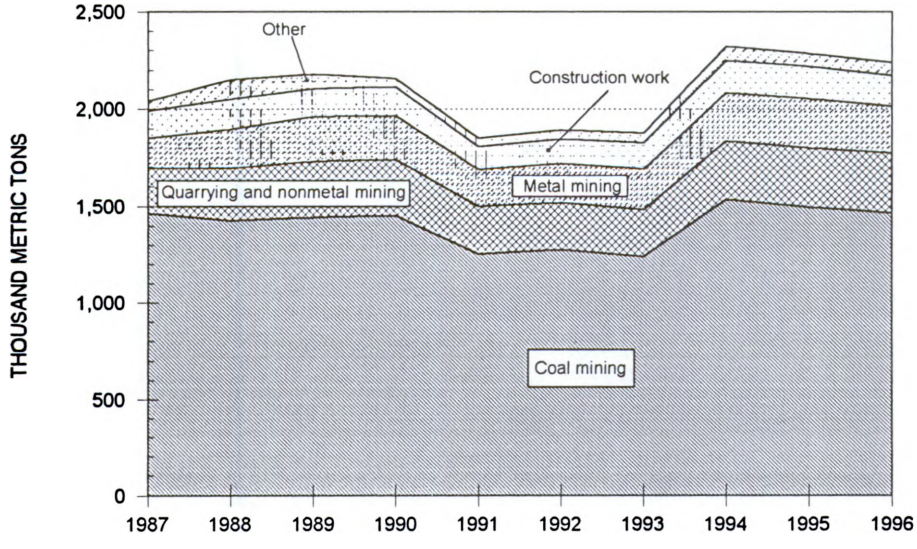


FIGURE 2
DEMAND TREND FOR U.S. INDUSTRIAL EXPLOSIVES



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FELDSPAR AND NEPHELINE SYENITE

By Michael J. Potter

Feldspar

Feldspars are alumino-silicates with varying amounts of sodium, potassium, or calcium. In glassmaking, the largest end use, feldspar provides alumina for improving hardness, durability, and resistance to chemical corrosion; shipments of glass containers were projected to decrease by 2% in 1996 (Ceramic Industry, 1996a). In ceramics, feldspar is used as a flux, lowering the vitrifying temperature of a ceramic body during firing and forming a glassy phase. Housing starts, where feldspar is used in plumbing fixtures, glass fiber for insulation, and tile, were 1.4 million, an increase of 3% from activity in 1995 (Ceramic Industry, 1996b).

Production.—U.S. production of marketable feldspar (including aplite) in 1996 was 890,000 metric tons with a value of $39.4 million, according to the U.S. Geological Survey (USGS). Feldspar was mined in seven States, led by North Carolina and followed by, in descending order, California, Virginia, Georgia, Oklahoma, Idaho, and South Dakota. North Carolina accounted for about 54% of the total. Twelve U.S. companies had a total of 14 mine/plant operations—North Carolina had 5, California had 4, and the remaining 5 States listed above each had 1. South Carolina had a grinding (only) facility.

Domestic production data for feldspar were collected by the USGS by means of a voluntary survey. Of the 14 known mine/plant operations, 8, representing 57% of the total operations canvassed, reported production of about 578,000 tons, or 65% of the total shown in table 1. The estimated production of the nonrespondents, about 312,000 tons, was derived from past years' production levels and trends.

Consumption.—Of feldspar (including aplite) sold or used in the United States, 70% went into the manufacture of glass, including glass containers and glass fiber. Feldspar used in making pottery and other uses was 30% of the output.

World Review.—**Capacity.**—The data in table 8 are an approximation of rated capacity at yearend 1996. Because actual capacity data were not available, rated capacity was considered to approximate recent peak production during the past 5 years for the United States and foreign countries.

Brazil.—The Feldspar Corp., a U.S.-based company, is hoping to move into local production with a Brazilian partner within 2 years. Target output could reach 100,000 tons per year for domestic and export markets. However, the investment necessary to set up the project would be formally announced only after an evaluation of reserves. Brazil's current production is 150,000 tons per year (Industrial Minerals, 1996a).

Besides small operations, two other companies, Arqueana de Minérios and Prominex Mineração, both in Minas Gerais State, produced a combined total of about 50,000 tons per year of mainly potash feldspar (Kendall, 1996).

Canada.—Daren Resources Ltd.'s first-phase evaluation of its Similkameen feldspar property in British Columbia indicated high-quality potash feldspar, which could be used in glass and ceramics applications. The next phase of testing will be to determine what type of metallurgical processing might be applied (Industrial Minerals, 1996b).

Germany.—A journal article (Jakobs, 1996) described a kaolin/feldspar/quartz operation of Amberger Kaolinwerke Eduard Kick Gmbh (AKW), which is said to be the leading producer of potash feldspar in Europe. Also discussed was a comparison of various grinding systems in the production of feldspar and quartz powder. The ore source is part of the most important sedimentary feldspar deposits in the Hirschau-Schaittenbacher Basin of eastern Bavaria. Average values for raw material in the western part range from 6% to 12% for feldspar, 76% to 78% for quartz, and 10% to 14% for kaolin. In the eastern part, they are about 20% for kaolin and 80% for quartz. AKW was producing about 35,000 tons per year of feldspar powder and 40,000 tons per year of quartz powder. The company's Hirschau ore-processing plant uses grading, electrostatic separation, flotation, and other steps.

Namibia.—A paper (Mitchell and Evans, 1996) discussed the feasibility of producing glass and ceramic-grade feldspar from granite fines and tailings from a former Namibian tin mine. In a typical feldspar operation, extraction and size reduction may account for 20% to 25% of operating costs. Production of feldspar from feldspathic quarry fines and/or mine tailings would reduce these costs because the material has already been extracted and crushed. Magnetic separation and froth flotation produced a high-purity feldspar. Based on the laboratory results, the potential for scaling up the processing to a commercial scale could be a viable prospect.

Turkey.—A study was made to investigate the possibility of beneficiating low-grade pegmatite from the Sogut area. This ore comprises quartz, muscovite, kaolinite, albite, and sanidine. Pegmatite was ground in a ball mill, followed by three stages of flotation to remove mica, Fe_2O_3, and quartz. The best test result yielded a concentrate with 0.51% Fe_2O_3, which was used in sanitaryware, dinnerware, electrical porcelain, and tile body. For example, 20% to 30% pegmatite instead of 10% to 17% feldspar was used in sanitaryware, and 20% to 30% pegmatite instead of 12% to 17% feldspar was used in dinnerware. Results were said to be good (Sumer, 1996).

Current Research and Technology.—A journal article (Arvidson and Dillé, 1996) discussed advances in magnetic separation of industrial minerals in wet and dry applications. The first rare-earth magnetic separator (REMS) prototype model was developed in 1981, and a new generation of REMS was introduced between 1990 and 1991. Wet processing became available for medium-intensity applications. In one application, a feldspar producer upgraded its flotation product

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by using magnetic roll separators after a drying circuit. The upgrading consisted of magnetically removing fine, weakly magnetic muscovite and moderately magnetic biotite. In another application, a feldspar producer upgrading its feldspar product stream by flotation to remove quartz and a large amount of muscovite mica also used magnetic roll separation. This resulted in an Fe_2O_3 level of 0.08%. By using a three-stage magnetic separator, Fe_2O_3 levels were reduced further to 0.06%.

Outlook.—Glass containers have faced competition from plastic and metal. Consequently, some glass container manufacturers have been looking overseas to expand their markets. For example, Owens-Illinois, Inc. of Toledo, OH, acquired the largest glass container manufacturers in Hungary, Estonia, and Finland to capitalize on the emerging markets in Eastern Europe. Owens-Illinois also will be increasing capacity by about 20% during over the next 2 years in several of its Latin American plants (Ceramic Industry, 1996c).

The United States has been importing about 58% of its tile consumption. Also, foreign ownership represents a significant part of the U.S. industry with many major foreign firms having U.S. facilities (Ceramic Industry, 1996d).

In Europe, most countries recycle glass containers to some degree. Some examples of countries and their national recycling rate, according to one source were Denmark, 63%; Germany, 75%; Italy 53%; and the United Kingdom, 27% (Glass, 1996).

In Spain, data from glass container manufacturers showed a continued reactivation of the industry. The increasing popularity of glass containers is due to their quality and environmental credentials, such as recycling (Cano, 1996).

In the United Kingdom, with the market doing well, the outlook for glass packaging looks bright (Green, 1996).

Asia is the largest consumer of tile, accounting for about 36% of worldwide consumption. Most Asian countries produce mainly for their own consumption, with little trade, because of rapid growth of individual economies. Also, high customs duties on imported tiles are imposed by respective governments. Overall, Asia is projected to become dominant in the global tile industry (Tsai, 1996).

Nepheline Syenite

Nepheline syenite is a light-colored feldspathic rock comprising mostly soda and potash feldspars and nepheline. In glassmaking, nepheline syenite provides alumina and alkali and, as a flux, lowers the melting temperature, prompting faster melting and fuel savings. Nepheline syenite is used as a flux in sanitaryware, dinnerware, floor and wall tiles, and other whiteware.

In Canada, Unimin Canada, Ltd., has two deposits, at Nephton and Blue Mountain, and two processing plants 175 kilometers northeast of Toronto. An estimated 60% of the output went to U.S. markets; 20%, to the Canadian market; and 20%, to markets in Europe and other countries.

At yearend 1996, prices for Canadian nepheline syenite ranged from about $22 to $24 per ton (depending on iron content) for glass-grade, 30-mesh material, bulk, in car lots/truck lots and $69 per ton for ceramic-grade, 200-mesh, bagged, 1-ton lots (Industrial Minerals, 1996c, p. 73). The other producer was North Cape Minerals A/S at Stjernoya, Norway. An estimated 75% of the production was glass grade; the remainder was ceramic, amber, and filler grades. Sales were mostly to Europe.

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[1]Prior to January 1996, published by U.S. Bureau of Mines.

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TABLE 1
SALIENT FELDSPAR AND NEPHELINE SYENITE STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Feldspar:						
Produced 2/	metric tons	725,000	770,000	765,000	880,000	890,000
Value	thousands	$28,500	$31,400	$31,200	$37,400	$39,400
Exports	metric tons	17,700	17,700	17,300	14,700	10,200
Value	thousands	$2,210	$1,840	$1,940	$1,970	$1,390
Imports for consumption	metric tons	13,000	7,050	7,360	8,980	7,150
Value	thousands	$923	$514	$513	$813	$594
Nepheline syenite:						
Imports for consumption	metric tons	335,000	289,000	333,000	316,000	247,000
Value	thousands	$14,700	$15,400	$18,700	$19,700	$20,900
Consumption, apparent 3/						
(feldspar plus nepheline syenite)	thousand metric tons	1,060	1,050	1,090	1,190	1,130
World: Production (feldspar)	do.	5,990 r/	6,130 r/	6,420 r/	6,780 r/	6,750 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Includes hand-cobbed feldspar, flotation-concentrate feldspar, feldspar in feldspar-silica mixtures and aplite; includes potash feldspar (8% K_2O or higher).

3/ Production plus imports minus exports.

TABLE 2
FELDSPAR PRODUCED IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

	Flotation concentrate		Other 2/		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value
1995	397	17,400	485	20,000	880	37,400
1996	379	17,700	510	21,700	890	39,400

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes hand-cobbed, feldspar-silica mixtures (feldspar content), and aplite.

TABLE 3
PRODUCERS OF FELDSPAR AND FELDSPATHIC MATERIALS IN 1996

Company	Plant location	Product
APAC Arkansas Inc.	Muskogee, OK	Feldspar-silica mixture.
Corona Industrial Sand Co.	Corona, CA	Do.
The Feldspar Corp.	Monticello, GA	Potash feldspar.
Do.	Spruce Pine, NC	Soda-potash feldspar.
FMC Lithium Div.	Bessemer City, NC	Feldspar-silica mixture.
Franklin Industrial Minerals	Kings Mountain, NC	Potash feldspar.
PW Gillibrand Co.	Simi Valley, CA	Feldspar-silica mixture.
KT Feldspar Corp.	Spruce Pine, NC	Soda-potash feldspar.
Pacer Corp.	Custer, SD	Potash feldspar.
Santa Cruz Aggregates Co.	Felton, CA	Feldspar-silica mixture.
Spartan Minerals Corp.	Pacolet, SC	Do.
Unimin Corp.	Byron, CA	Do.
Do.	Emmett, ID	Do.
Do.	Spruce Pine, NC	Soda-potash feldspar.
U.S. Silica Co.	Montpelier, VA	Aplite.

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TABLE 4
FELDSPAR SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	1995		1996	
	Quantity	Value	Quantity	Value
Flotation concentrate:				
Glass	132	7,000	151	7,970
Pottery	230	14,700	231	14,900
Total	362	21,700	382	22,900
Other: 3/				
Glass	440	20,000	459	22,200
Pottery	W	W	W	W
Miscellaneous	W	W	W	W
Total	473	24,200	493	25,200
Total:				
Glass 4/	572	27,000	610	30,200
Pottery	W	W	W	W
Miscellaneous	W	W	W	W
Total	835	45,900	875	48,000

W Withheld to avoid disclosing company proprietary data; included in " Total."
1/ Includes potash feldspar (8% K2O or higher).
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes hand-cobbed, feldspar-silica mixtures (feldspar content), and aplite.
4/ Includes container glass, glass fiber, and other glass.

TABLE 5
PRICES FOR FELDSPAR, YEAREND 1996

(Dollars per metric ton, bulk, ex-works, USA)

	Price
Glass grade:	
30 mesh, soda	44-55
80 mesh, potash	88
Ceramic grade:	
170 to 250 mesh, soda	66-77
200 mesh, potash	105

Source: Industrial Minerals (London), No. 351, Dec. 1996, p. 72.

TABLE 6
U.S. EXPORTS OF FELDSPAR, BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value	Quantity (metric tons)	Value
Canada	1,780	$240,000	1,250	$190,000
Ecuador	--	--	1,990	135,000
France	--	--	736	78,000
Italy	3,780	564,000	1,310	487,000
Mexico	7,980	870,000	1,600	227,000
Panama	--	--	2,510	133,000
Taiwan	217	63,800	--	--
Thailand	343	63,200	320	59,500
Venezuela	--	--	271	32,900
Other	546	161,000	174	50,500
Total	14,700	1,970,000	10,200	1,390,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF FELDSPAR, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/	1996 Quantity (metric tons)	1996 Value 2/
Mexico	8,490	$642,000	6,920	$516,000
Other	488	171,000	233	78,000
Total	8,980	813,000	7,150	594,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

TABLE 8
WORLD FELDSPAR ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1996 1/ 2/

(Thousand metric tons)

	Rated capacity
North America:	
Mexico	160
United States	890
Total	1,050
South America:	
Argentina	56
Brazil	205
Colombia	78
Venezuela	220
Other	35
Total	594
Europe:	
Finland	51
France e/	632
Germany	385
Italy	1,810
Norway e/	100
Poland	46
Portugal	100
Russia e/	100
Spain	247
Uzbekistan e/	80
Other	134
Total	3,680
Africa:	
South Africa	49
Other	53
Total	102
Asia and Oceania:	
India	99
Iran	77
Japan	72
Korea, Republic of	322
Thailand	670
Turkey	503
Other	88
Total	1,830
World total	7,260

e/ Estimated.
1/ Includes capacities of operating plants as well as plants on standby basis.
2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 9
FELDSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria	4,647	6,500	6,000 e/	6,000 e/	6,000
Argentina	48,509	55,764	39,825 r/	36,901 r/	37,000
Australia e/	15,000	15,000	16,000	16,000	17,000
Austria	11,059	8,492	4,883	5,000 e/	4,500
Brazil (crude)	202,632 r/	205,000 r/	205,000 r/ e/	205,000 r/ e/	205,000
Burma 4/	1,618	6,289	6,976	7,000 e/	6,500
Chile	5,744	4,149	9,967	10,000 e/	9,000
Colombia	78,446	60,458	76,188 r/	58,100 r/	60,000
Ecuador	3,251	2,015 r/	2,200 r/	2,000 r/ e/	2,000
Egypt	32,326	38,900 e/	39,745	39,800 e/	6,000
Finland	47,500	51,477	43,483 r/	45,000 r/ e/	45,000
France e/	282,000	274,000	390,000 r/	632,000 r/ 5/	600,000
Germany	384,747	360,154	379,427 r/	350,000 e/	375,000
Greece e/	26,600	15,000	35,000	30,000	30,000
Guatemala e/	8,048 5/	7,500	7,600	7,700	7,700
India	67,743	66,792	64,693 r/	98,683 r/	90,000
Iran	52,120	76,873	75,000 e/	75,000 e/	6,000
Italy	1,387,968 r/	1,534,210 r/	1,806,935 r/	1,800,000 r/ e/	1,800,000
Japan 6/	72,285	71,568	56,007	65,086 r/	58,542 5/
Kenya e/	1,200	1,200	1,200	1,200	1,500
Korea, Republic of	281,083	321,964	319,658	320,000 e/	320,000
Macedonia e/	20,000	15,000	15,000	15,000	15,000
Mexico	159,718	123,512	133,441 r/	121,779 r/	130,000
Morocco e/	1,000	1,000	1,000	1,000	1,000
Nigeria e/	700	700	700	700	700
Norway e/ 7/	100,000	75,000 r/	62,905 r/ 5/	65,000 r/	65,000
Pakistan	19,166	17,034	15,335 r/	21,163 r/	21,000
Peru	10,021	11,400 r/	11,400 r/ e/	11,400 r/ e/	11,400
Philippines	48,400 r/	44,600 r/	30,000 e/	30,000 e/	40,000
Poland	34,000	43,000	46,000 r/	46,000 r/ e/	45,000
Portugal	99,645	90,547	92,440 r/	74,000 r/ e/	75,000
Romania	27,715	87,701	10,400	10,000 e/	10,000
Russia e/	100,000	70,000	55,000	55,000	45,000
Serbia and Montenegro	5,111	2,679	3,238	3,200 e/	3,200
South Africa	49,425	43,400	37,156	47,874 r/	45,000
Spain 8/	247,415	239,000	225,000 e/	225,000 e/	225,000
Sri Lanka	7,524	8,000 e/	12,280	12,000 e/	13,000
Sweden	34,598	35,492 r/	44,520 r/	30,000 e/	30,000
Taiwan	2,216	1,716	778	-- r/	--
Thailand	559,806	600,835	554,227 r/	670,178 r/	650,000
Turkey	464,736	366,000	502,608 r/	400,000 e/	500,000
United Kingdom (china stone)	8,243	6,960	7,000 e/	7,000 r/ e/	8,000
United States	725,000	770,000	765,000	880,000	890,000 5/
Uruguay e/	3,000	3,000	3,000	3,000	2,500
Uzbekistan e/	80,000	70,000	70,000	70,000	70,000
Venezuela	168,689	220,000	136,507	170,404	170,000
Zambia e/	113 5/	100	100	100	100
Zimbabwe	2,696	1,553	1,617	1,600 r/ e/	1,650
Total	5,990,000 r/	6,130,000 r/	6,420,000 r/	6,780,000 r/	6,750,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 24, 1997.

3/ In addition to the countries listed, former Czechoslovakia, Madagascar, and Namibia produce feldspar, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

4/ Data are for fiscal years beginning Apr. 1 of that stated.

5/ Reported figure.

6/ In addition, the following quantities of aplite ore were produced in metric tons: 1992--416,304; 1993--403,724; 1994--381,160; 1995--388,000 (revised); and 1996--365,580.

7/ Excludes nepheline syenite.

8/ Includes pegmatite.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF NEPHELINE SYENITE 1/ 2/

Year	Quantity (metric tons)	Value 3/ (thousands)
1995	316,000	19,700
1996	247,000	20,900

1/ Crude and ground combined.
2/ Data are rounded to three significant digits.
3/ Customs value.

Source: Bureau of the Census.

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FERROALLOYS

By Michael Fenton

Ferroalloys are alloys of iron that contain one or more other chemical elements. These alloys are used to add these other elements into molten metal, usually in steelmaking. The following text contains some salient information on the ferroalloys chromium, manganese, and silicon. These and other ferroalloys are discussed in more detail, including domestic data coverage and outlook, in the respective commodity chapters in the Minerals Yearbooks. These chapters are also published individually in the Mineral Industry Surveys Annual Review series. The tables in this chapter comprise information on all ferroalloys for which data are available.

The major world producers of chromite ore are India, Kazakstan, South Africa, and Turkey; Brazil, Finland, and Zimbabwe were significant producers. Most chromite ore is smelted in an electric arc furnace to produce ferrochromium for use by the metallurgical industry. Stainless steel manufacture is the major end use of ferrochromium. The major producer of ferrochromium is South Africa; China, Finland, India, Japan, Kazakstan, and Zimbabwe are significant producers. The major producers of stainless steel—Western Europe, Scandinavia, Japan, and the United States—account for about 70% of world production.

Manganese ferroalloys are used to provide a key ingredient for steelmaking (Matricardi and Downing, 1995). Most of U.S. supply was imported; France and South Africa were leading sources. The sole domestic producer of manganese ferroalloys was Elkem Metals Co. at its plant in Marietta, OH.

China was by far the largest foreign producer of manganese ferroalloys, with an output more than twice that of either South Africa or Ukraine, the countries with the next largest outputs. Japanese and South African companies established joint ventures for production of refined and/or specialty grades of ferromanganese and silicomanganese in South Africa.

Demand for silicon ferroalloys is driven principally by the production of steel and cast iron (Dosaj, 1997). On the basis of content, U.S. production of silicon ferroalloys corresponded to roughly two-thirds of apparent consumption; Norway was the leading source of U.S. imports. China was estimated to be easily the world's largest producer of silicon ferroalloys. China's output was almost as great as that of the next four largest producing countries combined, which were Norway, Russia, Ukraine, and the United States. Silicon metal, which like ferrosilicon, was produced in submerged-arc electric furnaces, was used not as a ferroalloy, but rather for alloying with aluminum and for production of chemicals, especially silicones.

References Cited

Dosaj, V., 1997, Silicon and silicon alloys—Chemical and metallurgical, *in* Kirk-Othmer encyclopedia of chemical technology (4th ed.): New York, Wiley, v. 21, p. 1104-1122.

Matricardi, L., and Downing, J., 1995, Manganese and manganese alloys, *in* Kirk-Othmer encyclopedia of chemical technology (4th ed.): New York, Wiley, v. 15, p. 963-990.

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TABLE 1
GOVERNMENT INVENTORY OF FERROALLOYS, DECEMBER 31, 1996 1/

(Metric tons of alloy unless otherwise specified)

Alloy	Stockpile grade	Nonstockpile grade	Total
Ferrochromium:			
High-carbon	695,000	601	695,000
Low-carbon	272,000	10,400	283,000
Ferrochromium-silicon	51,400	1,240	52,700
Ferrocolumbium (kilograms contained columbium)	385,000	151,000	535,000
Ferromanganese:			
High-carbon	968,000	--	968,000
Medium-carbon	17,700	--	17,700
Ferrotungsten (kilograms contained tungsten)	385,000	533,000	918,000
Silicomanganese	183	--	183

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Defense Logistics Agency; Inventory of Stockpile Material L-1.

TABLE 2
REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ADDITIVES IN 1996, BY END USE 1/ 2/

(Metric tons of alloys unless otherwise specified)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
Steel:						
Carbon	257,000	93,500	52,800	3,090	3,750	687
Stainless and heat-resisting	13,100	6,020	40,500	1,560	(3/)	31
Other alloy	44,400	36,600	33,900	691	936	432
Tool	(4/)	(4/)	2,830	(3/)	--	--
Unspecified	578	371	142	(3/)	(3/)	--
Total steel	315,000	137,000	130,000	5,340	4,690	1,150
Cast irons	9,020	797	158,000	(5/)	930	(5/)
Superalloys	(5/)	--	346	747	--	46
Alloys (excluding alloy steels and superalloys)	1,140	(6/)	63,600	1,230	43	82
Miscellaneous and unspecified	(5/)	(6/)	265,000	(5/)	11	--
Grand total	326,000	137,000	617,000	7,310	5,670	1,280
Total 1995	348,000	130,000	537,000 r/	5,340 r/	5,860 r/	1,150 r/
Percentage of 1995	93	105	115	137	97	111
Consumer stocks, Dec. 31	27,300 7/	7,760 7/	20,300	721	1,030	220

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ FeMn, ferromanganese, including spiegeleisen and manganese metal; SiMn, silicomanganese; FeSi, ferrosilicon, including silicon metal, silvery pig iron, and inoculant alloys; FeTi, ferrotitanium, including titanium scrap and other titanium materials; FeP, ferrophosphorus, including other phosphorus materials; FeB, ferroboron, including other boron materials.

3/ Included with "Steel: Other alloy."

4/ Included with "Steel: Unspecified."

5/ Included with "Alloys (excluding alloy steels and superalloys)."

6/ Withheld to avoid disclosing company proprietary data.

7/ Includes producer stocks.

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TABLE 3
REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ALLOYING ELEMENTS IN 1996, BY END USE 1/ 2/

(Metric tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
Steel:						
Carbon	8,770	316	--	1,820	1,030	--
Stainless and heat-resisting	135,000 3/	343	2	22	413	21,800
Other alloy	25,300 3/	1,920	33	1,920	1,050	--
Tool	3,060	73	434	433	(4/)	--
Unspecified	474	25	--	W	7	--
Total steel	173,000	2,670	469	4,200	2,500	21,800
Cast irons	1,750	905	--	W	--	W
Superalloys	8,180 5/	57	W	16	509	--
Alloys (excluding alloy steels and superalloys)	1,680	87	W	389 6/	W	W
Miscellaneous and unspecified 7/	4,920	68	55	50	7	1,110
Grand total	190,000	3,790	522	4,650	3,020	22,900
Total 1995	193,000	3,370 r/	576 r/	4,650 r/	2,750 r/	21,700 r/
Percentage of 1995	98	112	91	100	110	106
Consumer stocks, Dec. 31	16,300 8/ 9/	966	27	301	290	8,690 10/

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ FeCr, ferrochromium, including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum, including calcium molybdate; FeW, ferrotungsten, including scheelite; FeV, ferrovanadium, including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium, including nickel columbium; FeNi, ferronickel.

3/ Part included with "Steel: Unspecified."

4/ Included with "Steel: Unspecified."

5/ Part included with "Alloys (excluding alloy steels and superalloys)."

6/ Part included with "Miscellaneous and unspecified."

7/ Includes mill products made from metal powder, pigments, catalysts, and other chemicals or ceramic uses.

8/ Includes some producer stocks.

9/ Part withheld to avoid disclosing company proprietary data.

10/ Secondary stocks not yet available.

TABLE 4
FERROALLOY PRICES IN 1996

	High	Low	Average 1/
Standard-grade ferromanganese 2/	575.00	480.00	531.88
Medium-carbon ferromanganese 3/	56.00	46.50	52.81
Silicomanganese 4/	39.50	23.75	28.35
Charge-grade ferrochromium 3/	64.00	39.80	51.27
High-carbon ferrochromium 3/	65.00	38.50	45.09
Low-carbon ferrochromium 3/	180.00	112.00	137.14
50%-grade ferrosilicon 3/	66.00	63.00	64.00
75%-grade ferrosilicon 3/	64.50	52.00	62.20
Silicon metal 4/	98.00	73.00	89.70
Ferromolybdenum 5/	7.00	4.30	5.11
Molybdenum oxide 5/	5.50	2.90	3.79
Ferrovanadium 6/	16.40	14.80	15.43

1/ Annual weighted average.

2/ Dollars per long ton.

3/ Cents per pound of contained element.

4/ Cents per pound.

5/ Dollars per pound of contained element.

6/ Dollars per kilogram of contained element.

Source: Platt's Metal Week.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF FERROALLOYS AND FERROALLOY METALS IN 1996 1/

(Metric tons unless otherwise specified)

Alloy	Imports			Exports		
	Gross weight	Contained weight	Value (thousands)	Gross weight	Contained weight	Value (thousands)
Ferroalloys:						
Chromium ferroalloys:						
Ferrochromium containing:						
More than 4% of carbon	359,000	207,000	$202,000	12,800	7,800	$9,650
More than 3% but not more than 4% of carbon	36	23	47	XX	XX	XX
Not more than 3% of carbon	60,700	38,400	87,200	2,780	1,630	4,020
Ferrochromium-silicon	49,600	17,300	32,500	252	88	286
Total	470,000	263,000	322,000	15,800	9,520	14,000
Manganese ferroalloys:						
Ferromanganese containing:						
More than 4% of carbon	284,000	220,000	126,000	XX	XX	XX
More than 2% of carbon	XX	XX	XX	3,120	2,460	1,970
More than 1% but not more than 2% of carbon	78,100	62,900	62,900	XX	XX	XX
Not more than 1% of carbon	11,500	10,200	17,300	XX	XX	XX
Ferromanganese, other	XX	XX	XX	6,680	5,280	6,880
Silicomanganese	323,000	213,000	188,000	5,270	3,420	4,390
Total	697,000	506,000	394,000	15,100	11,200	13,200
Silicon ferroalloys:						
Ferrosilicon containing:						
More than 55% of silicon	XX	XX	XX	12,400	7,560	10,500
More than 55% but not more than 80% of silicon and more than 3% of calcium	1,070	740	1,240	XX	XX	XX
More than 55% but not more than 80% of silicon and not more than 3% of calcium	180,000	136,000	164,000	XX	XX	XX
Magnesium ferrosilicon	8,910	4,100	9,230	39,300	19,700	35,600
Ferrosilicon, other	16,900	5,930	8,810	XX	XX	XX
Total	207,000	147,000	183,000	51,700	27,300	46,100
Other ferroalloys:						
Ferrocerium and other pyrophoric alloys and other	120	(2/)	1,980	XX	XX	XX
Ferromolybdenum	7,870	4,960	54,300	985	581	9,930
Ferronickel	43,400	16,000	111,000	5,650	3,330	32,700
Ferroniobium (columbium)	4,570	(2/)	42,100	254	(2/)	1,490
Ferrophosphorus	10,600	(2/)	5,920	4,420	(2/)	1,760
Ferrotitanium and ferrosilicon-titanium	7,720	(2/)	17,100	777	(2/)	2,330
Ferrotungsten and ferrosilicon-tungsten	702	535	3,410	3	2	22
Ferrovanadium	2,470	1,880	28,300	638	479	8,830
Ferrozirconium	212	(2/)	413	101	(2/)	228
Ferroalloys, other	33,900	(2/)	53,000	2,970	(2/)	6,080
Total	111,000	XX	317,000	15,800	XX	63,300
Total ferroalloys	1 480,000	XX	1 220,000	98,400	XX	137,000
Metals:						
Chromium	8,730	(2/)	61,300	1,330	(2/)	12,800
Manganese:						
Unwrought, other	10,100	(2/)	16,800	16,600	(2/)	23,000
Other, other	841	(2/)	2,600	3,630	(2/)	5,760
Silicon:						
Less than 99% of silicon	40,300	38,100	56,400	9,080	8820	13,200
Less than 99.99% but not less 99% of silicon	40,000	39,100	65,400	5,180	5,140	8,050
Not less than 99.99% of silicon	1,520	1,520	92,400	2,750	2,750	188,000
Total	102,000	XX	295,000	38,600	XX	251,000
Grand total	1,590,000	XX	1,510,000	137,000	XX	387,000

XX Not applicable.
1/ Data rounded by the U.S. Geological Survey to three significant digits; may not add to totals shown.
2/ Not recorded.

Source: Bureau of the Census.

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TABLE 6
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Albania: Electric furnace, ferrochromium	21,650 r/	35,600 r/	33,764 r/	42,986 r/	31,189 5/
Argentina: Electric furnace:					
Ferromanganese	4,524	5,400	8,117 r/	5,836 r/	6,000
Ferrosilicon	8,073	19,579	11,669 r/	9,000 e/	10,000
Silicomanganese	30,790	18,500	29,358 r/	27,344 r/	28,000 5/
Other 6/	3,600 r/	5,821 r/	3,700 r/ e/	3,850 r/ e/	3,750
Total	46,987	49,300	52,844 r/	46,030 r/	47,800
Australia: Electric furnace: e/					
Ferromanganese	55,000	75,000	100,000	110,000 r/	110,000
Ferrosilicon	17,000	--	--	--	--
Silicomanganese	75,000	75,000	100,000	100,000 r/	95,000
Silicon metal	30,000	30,000	30,000	30,000	30,000
Total	177,000	180,000	230,000	240,000	235,000
Austria: Electric furnace: e/					
Ferronickel	9,750 5/	8,000 5/	5,250	6,200	5,000
Other	5,900	5,900	5,900	5,900	5,900
Total	15,700	13,900	11,200	12,100	10,900
Belgium: Electric furnace, ferromanganese e/	25,000	25,000	25,000	25,000	25,000
Bhutan: Electric furnace, ferrosilicon e/	--	--	2,000	12,000	12,000
Bosnia and Herzegovina: Electric furnace: e/					
Ferrosilicon	5,000 5/	1,000	1,000	1,000	1,000
Silicon metal	2,000 5/	200	200	200	200
Other	500 5/	--	--	--	--
Total	7,500 5/	1,200	1,200	1,200	1,200
Brazil: Electric furnace:					
Ferrochromium 7/	91,100	83,892	77,163	95,840	72,609 5/
Ferrochromiumsilicon e/	6,760	4,500	5,000	5,000	5,000
Ferromanganese	178,937	201,518	200,000	130,000 e/	160,000
Ferronickel	34,968	34,732	35,260	34,000 e/	34,000
Ferrosilicon	243,838	248,147 r/	198,505	243,824	240,000
Silicomanganese	299,995	284,147	248,000	167,000 e/	210,000
Silicon metal	93,734	106,000	110,000	116,000 r/ e/	165,000
Other e/	76,654 5/	76,000	76,000	76,000	76,000
Total	1,025,986	1,038,936 r/	949,928	867,664 r/	963,000
Bulgaria: Electric furnace: e/					
Ferrosilicon	18,000	18,000	8,000 r/	7,550 r/	8,300
Other	2,000	2,000	2,000	2,000	2,000
Total	20,000	20,000	10,000 r/	9,550 r/	10,300
Canada: Electric furnace: e/					
Ferrosilicon	55,000	55,000	55,000	56,000	56,000
Ferrovanadium	2,000	2,000	2,000	1,000	1,000
Silicon metal	20,000	20,000	20,000	22,000	22,000
Total	77,000	77,000	77,000	79,000	79,000
Chile: Electric furnace:					
Ferrochromium	2,110	680	1,579	2,730	2,700
Ferromanganese	7,460	8,916	8,500 e/	8,500 e/	8,500
Ferromolybdenum	2,310	2,202	2,300 e/	2,300 e/	2,300
Ferrosilicon e/	3,830	7,550	5,600	5,600	5,500
Silicomanganese	1,564	1,612	1,700	1,600 e/	1,600
Total e/	17,300	21,000	19,700	20,700	20,600
China: e/ 8/					
Blast furnace:					
Ferromanganese	550,000	520,000	567,000	400,000 r/	400,000
Other	180,000	200,000	210,000	210,000	200,000
Electric furnace:					
Ferrochromium	410,000	372,000	370,000	400,000	450,000
Ferromanganese	200,000	220,000	350,000	605,000 r/	550,000
Ferrosilicon	834,000	1,040,000	1,100,000	1,210,000 r/	1,200,000
Silicomanganese	420,000	525,000	657,000	830,000 r/	800,000
Other	56,000	58,000	110,000	80,000	100,000
Total	2,650,000	2,930,000	3,360,000	3,740,000 r/	3,700,000
Colombia: Electric furnace, ferronickel	49,256	48,624	50,827	59,917	57,335 5/

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Croatia: Electric furnace:					
Ferrochromium	56,456	27,336	31,704 r/	26,081 r/	10,559 5/
Ferromanganese e/	10,000	10,000	10,000	10,000	10,000
Silicomanganese e/	15,000	40,000	30,000	30,000	30,000
Total e/	81,500	77,300	71,700	66,100 r/	50,600
Czech Republic: 9/ Electric furnace e/	XX	1,000	1,000	1,000	1,000
Czechoslovakia: 10/ Electric furnace: e/					
Ferrochromium 7/ 11/	52,500 5/	XX	XX	XX	XX
Ferromanganese 12/	70,000	XX	XX	XX	XX
Ferrosilicon	15,000	XX	XX	XX	XX
Silicon metal	5,000	XX	XX	XX	XX
Other 13/	10,000	XX	XX	XX	XX
Total	153,000	XX	XX	XX	XX
Dominican Republic: Electric furnace, ferronickel	72,447	62,787	80,989	81,297	80,000 5/
Egypt: Electric furnace:					
Ferromanganese e/	10,000	30,000	35,000	35,000	35,000
Ferrosilicon	36,038	40,136	44,000 r/	44,000 r/ e/	44,000
Total	46,038	70,136	79,000 r/	79,000 r/ e/	79,000
Finland: Electric furnace, ferrochromium	187,100	218,370	253,501 r/	246,805 r/	236,000
France:					
Blast furnace, ferromanganese	280,000 e/	300,000	294,000	304,000 r/	300,000
Electric furnace:					
Ferrochromium	6,694	--	--	--	--
Ferromanganese	60,000	57,000	66,200	100,000 r/	80,000
Ferrosilicon	98,000	84,000 r/	111,000	108,000 r/	110,000
Silicomanganese 14/	80,000	80,000	75,000 e/	80,000 e/	80,000
Silicon metal	66,000 r/	59,000	66,000 r/	71,000 r/	65,000
Other e/ 15/	32,000	29,000	20,000	20,000	20,000
Total e/	623,000 r/	609,000 r/	632,000 r/	683,000 r/	655,000
Georgia: Electric furnace: e/					
Ferromanganese	100,000	100,000	10,000	5,000	5,000
Silicomanganese	50,000	50,000	40,000	25,000	15,000
Other	10,000	10,000	5,000	5,000	5,000
Total	160,000	160,000	55,000	35,000	25,000
Germany: e/					
Blast furnace, ferromanganese 16/	130,000	100,000	--	--	--
Electric furnace:					
Ferrochromium	26,520 5/	16,400 5/	17,283 5/	18,000 r/ 5/	16,000
Ferromanganese 12/	30,000	20,000	20,000	20,000	20,000
Ferrosilicon	20,000	20,000	20,000	20,000	20,000
Silicon metal	500	500	500	500	500
Other 13/	30,000	30,000	30,000	30,000	30,000
Total	237,000	187,000	87,800	88,500 r/	86,500
Greece: Electric furnace, ferronickel	73,429	52,067	77,129	81,733	86,000
Hungary: 17/ Electric furnace: e/					
Ferrosilicon	7,000	7,000	7,000	7,000	7,000
Silicon metal	1,000	1,000	1,000	1,000	1,000
Other	1,000	1,000	1,000	--	--
Total	9,000	9,000	9,000	8,000	8,000
Iceland: Electric furnace, ferrosilicon	51,651	67,375	66,003	71,410 r/	72,000
India: Electric furnace: e/					
Ferrochromium 18/	192,674 r/ 5/	234,500 5/	251,459 5/	300,000	300,000
Ferrochromiumsilicon	9,000	8,000	8,000	9,000	9,000
Ferromanganese	198,000	137,291 5/	150,000	150,000	150,000
Ferrosilicon	90,000	67,600	85,000	85,000	85,000
Silicomanganese	93,000	85,000 5/	140,000	120,000 r/	120,000
Other	6,500	8,600	8,500	8,500	8,500
Total	589,000 r/	541,000	643,000	673,000 r/	673,000
Indonesia: Electric furnace:					
Ferromanganese e/	--	10,000	10,000	14,000	14,000
Ferronickel	27,530 r/	26,330 r/	28,725 r/	53,675	55,000
Silicomanganese e/	--	--	--	7,000	7,000
Total	27,530 r/	36,330 r/	38,725 r/	74,675	76,000

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Iran: Electric furnace: e/					
Ferrochromium 19/	--	--	5,000	115,000 r/ 5/	150,000
Ferrosilicon	--	--	--	10,000	20,000
Total	--	--	5,000	125,000 r/	170,000
Italy: Electric furnace:					
Ferrochromium	60,315	53,504	22,650	51,017	29,915 5/
Ferromanganese e/	17,079 5/	17,000	16,000	16,000	16,000
Ferrosilicon	3,350	--	--	--	--
Silicomanganese e/	50,000	50,000	40,000	40,000	50,000
Silicon metal	10,000	10,000 e/	--	--	--
Other e/ 20/	12,000	12,000	12,000	12,000	10,000
Total e/	153,000	143,000	90,700	119,000	106,000
Japan: Electric furnace:					
Ferrochromium 21/	267,857	204,719	192,989	210,445	193,695 5/
Ferromanganese	361,941	382,912	345,153	346,977	343,104 5/
Ferronickel	237,350	257,316	242,447	351,337	328,699 5/
Ferrosilicon	37,656	29,084	12,208	3,650	-- 5/
Silicomanganese	96,360	64,758	69,183	64,870	75,802 5/
Other 22/	12,189	13,666	14,647	12,353	13,206 5/
Total	1,013,353	952,455	876,627	989,632	954,506 5/
Kazakstan: Electric furnace: e/					
Ferrochromium	400,000	327,896 5/	200,000	486,000 r/ 5/	352,000 5/
Ferrochromiumsilicon	40,000	30,000	20,000	25,000	20,000
Ferrosilicon	500,000	450,000	250,000 r/	256,000 r/	119,000
Silicomanganese	--	--	40,000	20,000	50,000
Other	20,000	15,000	10,000	10,000	10,000
Total	,960,000	823,000	520,000 r/	797,000 r/	551,000
Korea, North: Electric furnace: e/					
Ferromanganese 12/	70,000	70,000	70,000	70,000	70,000
Ferrosilicon	30,000	30,000	30,000	30,000	30,000
Other 13/	20,000	20,000	20,000	20,000	20,000
Total	120,000	120,000	120,000	120,000	120,000
Korea, Republic of: Electric furnace:					
Ferromanganese	85,867	100,630	120,020	119,000 r/ e/	126,000
Ferrosilicon	55	--	--	--	--
Silicomanganese	82,582	81,996	89,023	97,800 r/ e/	83,000
Total	168,504	182,626	209,043	217,000 r/ e/	209,000
Macedonia: Electric furnace: e/					
Ferrochromium	3,958 5/	4,376 5/	3,164 5/	3,765 5/	3,780 5/
Ferrochromiumsilicon	1,500	--	--	--	--
Ferronickel	4,500	3,500	3,500	3,500	3,000
Ferrosilicon	30,000	20,000	20,000	15,000	15,000
Silicon metal	1,000	1,000	1,000	1,000	1,000
Total	41,000 r/	28,900 r/	27,700 r/	23,300 r/	22,800
Mexico: Electric furnace:					
Ferrochromium	70 e/	--	--	--	-- 5/
Ferromanganese	79,000	70,000 e/	67,000 e/	58,000	69,000 5/
Ferrosilicon e/	5,000 5/	400	400	--	-- 5/
Silicomanganese	51,000	55,000 e/	64,000 e/	67,700	93,000 5/
Other e/	300 5/	300	300	--	-- 5/
Total e/	135,000	126,000	132,000	125,700 5/	162,000 5/
New Caledonia: Electric furnace, ferronickel	127,580	147,400	157,952	168,800	169,000
Norway: Electric furnace:					
Ferrochromium	102,000	80,000	120,000	137,000 r/	110,000 5/
Ferromanganese	202,680	226,018	248,648	225,000 e/	225,000
Ferrosilicon	367,034	399,559	452,984	474,000 r/	462,000 5/
Silicomanganese	213,106	218,566	197,328	200,000 e/	200,000
Silicon metal	73,000 r/	81,000 r/	92,000 r/	101,000 r/	110,000
Other e/ 14/	14,000	14,000	14,000	15,000	15,000
Total e/	972,000 r/	1,020,000 r/	1,120,000 r/	1,150,000 r/	1,120,000
Peru: Electric furnace, ferrosilicon e/	600	600	600	600	600

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Philippines: Electric furnace:					
Ferrochromium	27,400	11,908	16,186	50,450 r/	--
Ferromanganese e/	5,000	5,000	5,000	5,000	--
Ferrosilicon e/	10,000	10,000	10,000	10,000	--
Total e/	42,400	26,900	31,200	65,500	--
Poland:					
Blast furnace: Ferromanganese	43,400 r/	56,400	66,300 r/	46,300 r/	45,000
Electric furnace:					
Ferrochromium	35,322	38,449	7,353 r/	18,334	18,000
Ferromanganese	4,800	1,100	-- r/	-- r/	--
Ferrosilicon	36,100	43,100	54,200 r/	70,400 r/	70,000
Silicomanganese e/	25,000	25,000	25,000	25,000	25,000
Silicon metal e/	1,300 r/	1,300 r/	1,300 r/	1,300 r/	1,300
Other e/ 13/	25,000	20,000	20,000	20,000	20,000
Total e/	171,000 r/	185,000 r/	174,000 r/	181,000 r/	179,000
Romania: Electric furnace:					
Ferrochromium	6,971 r/	3,907	3,885	15,053	9,650 5/
Ferromanganese e/	27,100 r/	16,400	31,300	28,410 5/	20,200
Ferrosilicon	23,300	23,600	28,385	19,320	23,827 5/
Silicomanganese e/	28,200	22,000	35,200	57,149 5/	78,600
Silicon metal e/	430 5/	400	300	300	300
Total e/	86,000 r/	66,300	99,100	120,000	133,000
Russia: e/					
Blast furnace:					
Ferromanganese	200,000	150,000	55,000	55,000	55,000
Ferrophosphorus	30,000	25,000	20,000	20,000	20,000
Spiegeleisen	10,000	8,000	7,000	7,000	7,000
Electric furnace:					
Ferrochromium	400,000	255,900 5/	265,525 5/	200,000	50,000
Ferrochromiumsilicon	60,000	40,000	40,000	30,000	5,000
Ferronickel	46,000	47,000	59,000	77,000	75,000
Ferrosilicon	500,000	400,000	350,000	350,000	350,000
Silicomanganese	--	--	--	700	--
Silicon metal	60,000	50,000	40,000	40,000	40,000
Other	60,000	50,000	40,000	40,000	40,000
Total	1,370,000	1,030,000	877,000	820,000 r/	642,000
Serbia and Montenegro: Electric furnace, ferronickel	6,481	1,283	1,763	2,414	6,554 5/
Slovakia: 10/ Electric furnace: e/					
Ferrochromium	XX	50,600 5/	48,555 5/	65,260 5/	65,000
Ferromanganese	XX	22,000	25,000	25,000	25,000
Ferrosilicon	XX	22,000	30,000	30,000	30,000
Silicomanganese	XX	12,000	12,000	12,000	12,000
Other	XX	8,000	8,000	8,000	8,000
Total	XX	115,000 r/	124,000 r/	140,000 r/	140,000
Slovenia: Electric furnace: e/					
Ferrochromium	17,104 5/	9,000 5/	12,592 5/	18,876 5/	19,000
Ferrosilicon	14,000	12,000	12,000	12,000	10,000
Other 6/	5,400 r/	200 r/	200 r/	200 r/	200
Total	36,500	21,200	24,800	31,100	29,200
South Africa: Electric furnace:					
Ferrochromium 23/	770,600	833,600	1,103,612	1,386,400 r/	1,400,000
Ferromanganese	269,807	393,372	590,535	507,000 r/	480,000
Ferrosilicon	63,900	98,800	119,714	92,667 r/	96,000
Silicomanganese	266,556	268,123	290,400	251,000 r/	250,000
Silicon metal	34,528	38,279	36,169	30,082	35,000
Other e/	1,000	1,000	1,000	1,000	1,000
Total e/	1,410,000	1,630,000	2,140,000	2,270,000 r/	2,260,000

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Spain: Electric furnace: e/					
Ferrochromium	--	2,390 5/	2,300 5/	1,320 5/	805 5/
Ferromanganese	50,000	40,000	35,000	25,000	25,000
Ferrosilicon	40,000	30,000	25,000	30,000	30,000
Silicomanganese	40,000	35,000	35,000	50,000 r/	50,000
Silicon metal	10,000	5,000	3,000	5,000	5,000
Other	5,000	5,000	4,000	5,000	5,000
Total	145,000	117,000	104,000	116,000 r/	116,000
Sweden: Electric furnace:					
Ferrochromium	133,300	127,543	134,076	130,170 r/	138,110 5/
Ferrosilicon	15,451	20,381	21,392 r/	21,970 r/	21,000
Total	148,751	147,924	155,468 r/	152,140 r/	159,000
Switzerland: Electric furnace: e/					
Ferrosilicon	3,000	3,000	-- r/	-- r/	--
Silicon metal	2,000	2,000	-- r/	-- r/	--
Total	5,000	5,000	-- r/	-- r/	--
Taiwan: Electric furnace:					
Ferromanganese	38,000	13,628	7,000	5,000 e/	5,000
Ferrosilicon	2,606	689	500 e/	400 e/	500
Silicomanganese	4,000	--	--	--	--
Total	44,606	14,317	7,500	5,400 e/	5,500
Thailand: Electric furnace:					
Ferromanganese	549	70	140	150 e/	150
Silicomanganese	4,275	1,503	689	650 e/	650
Total	4,824	1,573	829	800 e/	800
Turkey: Electric furnace:					
Ferrochromium	85,755	90,030	97,585	94,251 r/	101,450 5/
Ferrosilicon	1,250	4,680	4,930	11,900 r/	12,000
Total	87,005	94,710	102,515	106,151 r/	113,000
Ukraine: e/					
Blast furnace:					
Ferromanganese	50,000	40,000	30,000	25,000 r/	30,000
Spiegeleisen	5,000	4,000	3,000	2,500	2,500
Electric furnace:					
Ferromanganese	250,000 r/	140,000 r/	170,000 r/	170,000 r/	190,000
Ferronickel	98,333 r/ 5/	50,000	23,000	23,000	8,300
Ferrosilicon	500,000	400,000	300,000 r/	300,000	300,000
Silicomanganese	1,100,000 r/	735,000 r/	600,000 r/	600,000 r/	650,000
Other	40,000	30,000	25,000	25,000	25,000
Total	2,040,000 r/	1,400,000 r/	1,150,000 r/	1,150,000 r/	1,210,000
United Kingdom:					
Blast furnace, ferromanganese	137,000	45,000	--	--	--
Electric furnace, other e/	10,000	10,000	--	--	--
Total e/	147,000	55,000	--	--	--
United States: Electric furnace:					
Ferrochromium 24/	60,900	63,000	67,400	72,500	36,800 5/
Ferronickel	18,200	9,930	--	16,800	30,500 5/
Ferrosilicon	346,000	323,000	359,000	358,000	362,000 5/
Silicon metal	159,000	159,000	158,000	158,000	171,000 5/
Other 25/	190,000	161,000	200,000	188,000	99,000 5/
Total	773,000	715,000	784,000	793,000	699,000 5/
Uruguay: Electric furnace, ferrosilicon e/	250	250	250	200 r/	250
Venezuela: Electric furnace: e/					
Ferromanganese	8,570	--	--	--	--
Ferrosilicon	40,000	47,000	41,000	50,000 r/	50,000
Silicomanganese	32,100	42,200	40,000	40,000	40,000
Total	80,700	89,200	81,000	90,000 r/	90,000
Zimbabwe: Electric furnace:					
Ferrochromium	190,994	124,000	182,852	254,142	261,918 5/
Ferrochromiumsilicon	20,282	10,000 e/	36,531	46,667	33,175 5/
Ferromanganese	--	2,151	--	--	--
Total	211,276	136,151	219,383	300,809	295,093 5/

See footnotes at end of table.

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TABLE 6--Continued
FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE 1/ 2/

(Metric tons, gross weight)

Country, furnace type, 3/ and alloy type 4/	1992	1993	1994	1995	1996 e/
Grand total:	16,900,000 r/	15,900,000 r/	16,200,000 r/	17,500,000 r/	17,000,000
Of which:					
Blast furnace:					
Ferromanganese 26/	1,390,000	1,210,000	1,010,000 r/	830,000 r/	830,000
Spiegeleisen 26/	15,000	12,000	10,000	9,500	9,500
Other 27/	210,000	225,000	230,000	230,000	220,000
Total, blast furnace	1,620,000	1,450,000	1,250,000 r/	1,070,000 r/	1,060,000
Electric furnace:					
Ferrochromium 28/	3,610,000 r/	3,270,000	3,520,000	4,440,000 r/	4,060,000
Ferrochromiumsilicon	97,500	62,500	89,500	90,700	52,200
Ferromanganese 29/ 30/	2,420,000 r/	2,400,000 r/	2,720,000 r/	2,820,000 r/	2,770,000
Ferronickel	806,000 r/	749,000 r/	766,000 r/	960,000 r/	938,000
Ferrosilicon	4,070,000	4,040,000 r/	3,840,000 r/	4,030,000 r/	3,870,000
Silicomanganese 29/ 31/	3,060,000 r/	2,770,000 r/	2,860,000 r/	2,910,000 r/	3,040,000
Silicon metal	569,000	564,000 r/	559,000 r/	577,000 r/	647,000
Other 32/	639,000	577,000	632,000	588,000	518,000
Total, electric furnace	15,300,000 r/	14,400,000	15,000,000 r/	16,400,000 r/	15,900,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Aug. 25, 1997.

3/ To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operation is included with electric furnace production.

4/ To the extent possible, ferroalloy production of each country has been separated to show the following individual major types of ferroalloys: ferrochromium, ferrochromiumsilicon, ferromanganese, ferronickel, ferrosilicon, silicomanganese, silicon metal, and spiegeleisen. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically, but which definitely exclude those listed previously in this footnote, have been reported as "Other." Where one or more of the individual ferroalloys listed separately in this footnote have been inseparable from other ferroalloys owing to a nation's reporting system, deviations are indicated by individual footnotes.

5/ Reported figure.

6/ Includes calciumsilicon.

7/ Includes high- and low-carbon ferrochromium.

8/ Estimated to have had an annual production capacity for silicon metal in excess of 200,000 tons in 1995. Data for actual production are not available.

9/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

10/ Dissolved Dec. 31, 1992.

11/ All production in Czechoslovakia for 1992 came from Slovakia.

12/ Includes silicomanganese, if any.

13/ Includes ferrochromiumsilicon and ferronickel, if any.

14/ Includes silicospiegeleisen, if any.

15/ Includes ferronickel if any.

16/ Includes spiegeleisen, if any.

17/ Hungary is believed to produce some blast furnace ferromanganese.

18/ Includes ferrochrome and charge chrome.

19/ Production began in 1994. Plant capacity is estimated to be 7,000 tons per year.

20/ Series excludes calcium silicide.

21/ Includes net consumption of ferrochromiumsilicon.

22/ Includes calciumsilicon, ferrocolumbium, ferromolybdenum, ferrotungsten, ferrovanadium, and other ferroalloys.

23/ Includes production from Bophuthatswana and net production of ferrochromiumsilicon, if any.

24/ U.S. output of ferrochromium includes high- and low-carbon ferrochromium, ferrochromiumsilicon, chromium metal, and other chromium materials.

25/ May include ferroaluminum, ferroboron, and other complex boron additive alloys, ferromanganese, ferromolybdenum, ferrotitanium, ferrovanadium, manganese metal, silicomanganese, and silvery pig iron.

26/ Spiegeleisen, if any, for Germany is included with blast furnace ferromanganese.

27/ Includes ferrophosphorus and data contained in "Blast furnace: Other."

28/ Ferrochromium includes ferrochromiumsilicon, if any, for Japan, South Africa, and the United States.

29/ Ferromanganese includes silicomanganese, if any, for countries carrying footnote 12 on "Ferromanganese" data line.

30/ U.S. production under "Other."

31/ Includes silicospiegeleisen, if any, for France.

32/ Includes calciumsilicon, ferromolybdenum, ferrovanadium, and data contained in "Electric furnace: Other" for each country indicated.

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FLUORSPAR

By M. Michael Miller

Traditionally, fluorspar has been considered vital to the Nation for both national security and economic reasons. It is used directly or indirectly to manufacture products such as aluminum, gasoline, insulating foams, refrigerants, steel, and uranium fuel. Most fluorspar consumption and trade involves either acid grade, which is greater than 97% calcium fluoride (CaF_2) or metallurgical grade, which is 97% or less CaF_2.

With the closure of Ozark-Mahoning Company's operations in southern Illinois in late 1995, the United States ended 158 years of mining fluorspar. Remaining company stocks were shipped during the first quarter of 1996, but accounted for only an estimated 8,200 metric tons. Material from the National Defense Stockpile (NDS) made it into the U.S. supply through sales to consumers or distributors as did a small amount of synthetic fluorspar produced from industrial waste streams. Supplementing fluorspar as a domestic source of fluorine, but not included in fluorspar production or consumption calculations, was byproduct fluorosilicic acid production from some phosphoric acid producers. According to the Bureau of the Census and the U.S. Geological Survey (USGS), imports of fluorspar decreased by 8% compared with the 1995 figures. Hydrofluoric acid (HF) imports were 12% higher than those reported in 1995.

Legislation and Government Programs

The Defense Logistics Agency, Defense National Stockpile Center (DLA-DNSC), was authorized to sell about 136,000 metric tons (150,000 short dry tons [sdt]) of metallurgical grade and about 118,000 tons (130,000 sdt) of acid grade during fiscal year 1996 (October 1, 1995 to September 30, 1996). DLA-DNSC only sold about 15,500 tons (17,100 sdt) of metallurgical grade, but sold about 114,000 tons (125,000 sdt) of acid grade or nearly the maximum amount authorized. The DLA-DNSC sold an additional 32,700 tons (36,000 sdt) of acid grade during the fourth quarter of 1996, which falls under fiscal year 1997. Cumulative sales of fluorspar from the NDS, for calendar years 1992 through 1996, were about 89,000 tons (98,000 sdt) of metallurgical grade and about 490,000 tons (540,000 sdt) of acid grade. According to the DLA-DNSC's fiscal year 1997 Annual Materials Plan, total sales of about 45,400 tons (50,000 sdt) of metallurgical grade and about 163,000 tons (180,000 sdt) of acid grade were authorized for fiscal year 1997. Under current sales levels, the DLA-DNSC projects complete disposal of fluorspar stockpiles to be accomplished in 5 years for metallurgical-grade stocks and 2½ years for acid-grade stocks.

Production

Domestic production data for fluorspar were developed by the USGS from voluntary surveys of U.S. operations. Surveys were conducted to obtain fluorspar mine production and shipments and fluorosilicic acid production. The last domestic fluorspar mining operation closed in December 1995, but a survey request was sent to this operation to collect final shipments data for 1996. Reported production from this Illinois producer has been traditionally withheld to protect company proprietary data, but was used to generate an estimate of total domestic shipments. Of the 11 fluorosilicic acid operations surveyed, 10 respondents reported production, representing 100% of the quantity reported.

In 1996, Elf Atochem North America, Inc., signed an agreement to sell its Ozark-Mahoning mill facilities to Sogem-Afrimet, Inc. and Hastie Mining Co. The sale agreement did not include the mines, mineral rights, or mining equipment. After due diligence, the deal was expected to be finalized during the third quarter of 1997. The partners have named their venture Hastie/Sogem Minerals and operated the facility under a lease agreement, pending finalization of the purchase. They are washing, screening, and drying metallurgical- and acid-grade fluorspar imported or purchased from the NDS. The information was confirmed by A. Marshall (Sogem- Afrimet, Inc., oral commun., 1997). Seaforth Mineral & Ore Co., Inc., dried and screened imported or NDS fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, as did Applied Industrial Materials Corp. (AIMCOR) at its facility at Aurora, IN.

Silverspar Minerals, Inc., signed an option and sales agreement to purchase the Babb-Barnes fluorspar mine and mill properties near Salem, KY, from USX Corp. Under the agreement Silverspar's subsidiary Orbex Resources, Inc., performed a test run of the mill for several months in the spring of the year. Silverspar was unable to finance the purchase and the option expired. The information was confirmed by M. Mews (Silverspar Minerals, Inc., oral commun., 1997). USX Corp. subsequently sold the mill to the Savage Zinc Co., which does not plan to utilize the mill for fluorspar processing. The information was confirmed by W. Mitchell (Savage Zinc Co., oral commun., 1997).

Six companies operating 10 plants processing phosphate rock for the production of phosphoric acid sold or used a reported 67,400 tons of byproduct fluorosilicic acid at a value of about $8.49 million. This was equal to approximately 119,000 tons of 92% fluorspar equivalent. Fluorosilicic acid output increased by about 20% compared with 1995. Since

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fluorosilicic acid is a byproduct of the phosphate fertilizer industry and is not manufactured for itself alone, shortages may occur when phosphate fertilizer production goes down.

There is some recovery of synthetic fluorspar at stainless steel pickling plants and at petroleum alkylation plants, but traditionally most of this product has been disposed of in landfills rather than reused as fluorspar. Greater restrictions on the disposal of industrial wastes and improvements in recovery processes may change this practice. At present, an estimated 10,000 tons of synthetic fluorspar is being produced annually in the United States.

Consumption

Domestic consumption data for fluorspar were developed by the USGS from voluntary surveys of U.S. operations. The consumption survey was sent to 60 operations quarterly and to 4 additional operations annually. Of the operations surveyed quarterly, 92% responded. Of the operations surveyed on an annual basis, 100% responded. Estimates were made for some of the operations surveyed quarterly. *(See table 1.)*

Acid-grade fluorspar, containing greater than 97% CaF_2, was used primarily as a feedstock in the manufacture of HF and to produce aluminum fluoride (AlF_3). Ceramic-grade fluorspar, containing 85% to 95% CaF_2, was used for the production of glass and enamel, to make welding rod coatings, and as a flux in the steel industry. Metallurgical-grade fluorspar, containing 60% to 85% or more CaF_2, was used primarily as a fluxing agent by the steel industry. Fluorspar is added to the slag to make it more reactive. It increases the fluidity of the slag (by reducing its melting point) and thus increases the chemical reactivity of the slag. Reducing the melting point of the slag brings lime and other fluxes into solution to allow the absorption of impurities.

The level of total reported fluorspar consumption remained essentially unchanged in 1996. Reported consumption by the domestic HF industry in 1996 increased by nearly 4%, despite the closure of the Elf Atochem HF plant in early 1996. In order to conceal individual company proprietary data, fluorspar consumption data for HF are now being combined with consumption data for AlF_3 production. The reported consumption of fluorspar for non-HF/AlF_3 uses decreased by 19% compared with 1995. The data collected for these non-HF/AlF_3 markets do not accurately reflect the true size of these markets, which are larger than reported.

In the ceramic industry, fluorspar was used as a flux and as an opacifier in the production of flint glass, white or opal glass, and enamels. Fluorspar was used in the manufacture of aluminum, brick, cement, and glass fibers and was also used in the melt shop by the foundry industry.

Three companies reported fluorspar consumption for the production of HF for at least part of the year. The largest use of HF was for the production of a wide range of fluorocarbon chemicals, including fluoropolymers, hydrochlorofluorocarbons (HCFC's), and hydrofluorocarbons (HFC's). HCFC's and HFC's were produced by seven companies: AlliedSignal Corp., Ausimont USA Inc., E. I. du Pont de Nemours & Co. Inc. (DuPont), Elf Atochem North America Inc., I.C.I. Americas Inc., La Roche Chemicals Inc., and MDA Manufacturing Ltd. The latter is a joint venture between Daikin America Inc. and 3M Corp. producing HCFC-22 and hexafluoropropane for captive use in fluoropolymer manufacturing.

Some of the replacements for chlorofluorocarbons (CFC's) will be HCFC's 22, 123, 124, 141b, 142b, and 225. These HCFC substitutes have ozone-depletion potentials much lower than that of CFC 11, CFC 12, and CFC 113, which in total have accounted for more than 90% of CFC consumption. HCFC 22 has been used for home air conditioning for years, HCFC 141b and HCFC 142b have replaced most of the CFC 11 and CFC 12 used in foam blowing, and HCFC 225 has been introduced as a replacement for CFC solvents. Unfortunately, because of the current phaseout schedule for HCFC's and the likelihood that the schedule will be accelerated, the market for HCFC's will exist for only a relatively short time. Industry expects HCFC's to be produced and utilized at least through the end of this decade.

The HFC replacements have no ozone-depletion potential because they contain no chlorine atoms. The most successful HFC replacement compound is HFC 134a, which is the main replacement for CFC 12 in auto air conditioners and in medium-temperature-range refrigeration systems. Demand for HFC 134a is growing, but will never achieve the market size that CFC 12 did, and at present HFC 134a production capacity is running far ahead of demand. HFC's 32, 125, 143a, and 152a also are being produced domestically, but in much smaller quantities. These four HFC's hold potential for use by themselves or more likely as blends for specific uses, and some interim replacements may be mixtures of these compounds and HCFC's. HFC 227 is being evaluated for use in medical aerosols. HFC 245ca is being tested in low pressure centrifugal compressor chillers, and HFC's 245 and 356 are being tested as potential replacements for HCFC 141b in blowing agents for thermosets such as polyurethane. DuPont has developed its proprietary HFC 4310 as a replacement for CFC 113, HCFC's, and perfluorocarbon for use in drying fluids, cleaning and rinsing agents, defluxing agents, and in heat transfer media. Hydrofluoroethers have been developed by 3M to replace CFC's in various solvent cleaning applications.

The manufacture of AlF_3 for use in aluminum reduction cells was a major use of HF. In the Hall-Héroult process, alumina is dissolved in a bath of molten cryolite, AlF_3, and fluorspar to allow electrolytic recovery of aluminum. On average, worldwide the aluminum industry consumes about 21 kilograms (kg) of fluorides for each metric ton of aluminum produced. This ranges from 10 to 12 kg per ton in a modern prebaked aluminum smelter to 40 kg per ton in an older Soderberg smelter without scrubbers. AlF_3 was used by the ceramic industry to produce body and glaze mixtures and specialty refractory products. It was used in the manufacture of aluminum silicates and in the glass industry as a filler.

HF was consumed in the manufacture of uranium tetrafluoride that was used in the process of concentrating

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uranium isotope 235 for use as nuclear fuel and in fission explosives. It also was used in stainless steel pickling, petroleum alkylation, glass etching, and in oil and gas well treatment. HF was used as a cleaner and etcher in the electronics industry.

HF was used as the feedstock in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, herbicides, mouthwashes, decay-preventing dentifrices, plastics, and water fluoridation.

Byproduct fluorosilicic acid was sold or used for water fluoridation (48%), to make AlF_3 for the aluminum industry (27%), to make sodium silicofluoride (14%), and in other or unspecified uses (11%). *(See table 2.)*

Stocks

Consumer stocks at yearend were 117,000 tons, an increase of nearly 27% from the level reported in 1995. Consumer and distributor stocks contained an additional 234,000 tons purchased from the NDS, but still located at NDS depots. As of December 31, 1996, the NDS fluorspar inventory classified as excess (excluding material sold pending shipment) contained about 392,000 tons (432,000 sdt) of acid-grade material, about 187,000 tons (206,000 sdt) of metallurgical-grade material, about 677 tons (746 sdt) of nonstockpile, acid-grade material, and about 97,000 tons (107,000 sdt) of nonstockpile, metallurgical-grade material.

Transportation

The United States is import dependent for the majority of its fluorspar supply. Fluorspar is transported to customers by truck, rail, barge, and ship. Metspar is shipped routinely as lump or gravel, with the gravel passing a 75-millimeter sieve and not more than 10% by weight passing a 9.5-millimeter sieve. Acidspar is shipped routinely in the form of damp filtercake containing 7% to 10% moisture to facilitate handling and reduce dust.

Most acidspar imports come from China and South Africa. Fluorspar is shipped by ocean freight utilizing the "Tramp" market for ships. Bulk carriers of 10,000 to 50,000 tons deadweight normally are utilized. Participants negotiate freight levels, terms, and conditions. The main participants are *charterers*–generally the buyers or sellers, *ship owners*–who either own vessels or have them time chartered, *operators*–traders normally taking positions on either cargo or ships, and *brokers*–who generally represent ship owners or charterers and act as go betweens. Ships are primarily owned by the following: privately held shipping companies, publicly held shipping companies, government-controlled companies, and groups of professionally managed fleets under varying ownership. This information was confirmed by R.C. Diamond (Mid-Ship Marine, Inc., written commun., 1993). Until recently, the rate of new ship construction in the range of 10,000 to 50,000 tons had been very low, but during the 1996-97 period more than 300 new ships were due to be built. These new ships would drop the average age of the fleet to about 10 years.

This expansion of the smaller bulk carrier fleet would result in overcapacity and cause a likely decrease in shipping prices during the latter part of 1997. The new ships will make competition difficult for the older ships, which already may be burdened with the overage insurance frequently required on ships over 15 years in age. As a result, many of the older ships are expected to be scrapped. In addition, increased demand for grains and fertilizers in Asia, which are normally shipped on large bulk carriers, may affect the availability of the smaller bulk carriers favored by fluorspar shippers. These factors are expected to cause prices to rebound and to increase by 15% to 20%. This information was confirmed by Steven Rzehak (Mid-Ship Marine, Inc., oral commun., 1997).

Prices

Industrial Minerals (Metal Bulletin PLC) published yearend price ranges for Mexican fluorspar were $115 to $135 per ton for acid grade and $80 to $105 per ton for metallurgical grade. South African prices for acid grade, f.o.b. Durban, increased to $125 to $135 per ton. No specific f.o.b. China or c.i.f. Gulf of Mexico prices were available for Chinese fluorspar. According to Industrial Minerals, the average U.S. Gulf port price, dry basis, for acid grade was unchanged at $142 to $152 per ton. This would be the average delivered price of Chinese, Mexican, and South African acid grade at Gulf ports. *(See table 3.)*

Yearend price quotations from the Chemical Market Reporter (CMR) for anhydrous HF increased to $0.70 per pound. Aqueous HF, 70%, in drums, f.o.b., freight allowed, was unchanged at $62.00 per 100 pounds. These quotations were equivalent to about $1.55 per kilogram for anhydrous HF and $136.69 per 100 kilograms for aqueous HF, 70%, in drums. The CMR yearend price quotation for hydrofluosilicic acid (fluorosilicic acid), 23% basis, in tanks, Midwest and East Coast terminals, was unchanged at $165 per short ton (about $182 per metric ton).

Foreign Trade

According to the Bureau of the Census, U.S. exports of fluorspar increased by about 47%. All U.S. exports were believed to be reexports of material imported into the United States or exports of material purchased from the NDS. *(See table 4.)*

In 1996, imports for consumption of fluorspar decreased by 8% when compared with those of 1995, according to Bureau of the Census and USGS data. In descending order, China, South Africa, and Mexico were the largest suppliers of fluorspar to the United States. China accounted for more than 69% of U.S. fluorspar imports. The average c.i.f. unit value, in dollars per metric ton, was $142 for acid grade and $103 for subacid grade. *(See table 5.)*

There is a 13.5% ad valorem tariff on subacid-grade fluorspar imports that applies to both most-favored nation (MFN) and non-MFN countries. The tariff on acid grade for MFN countries is $1.24 per ton and for non-MFN countries

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$5.51 per metric ton. The North American Free Trade Agreement eliminates these tariffs on any fluorspar imported from Canada or Mexico.

Imports of HF, excluding material from DuPont's foreign trade zone, increased by 12% to a quantity equivalent to approximately 118,000 tons of fluorspar. Imports of synthetic and natural cryolite decreased 10% to a quantity equivalent to approximately 7,810 tons of fluorspar. Imports of AlF_3 decreased by nearly 18% to a quantity equivalent to 25,200 tons of fluorspar. *(See tables 6, 7, and 8.)*

World Review

The industry experienced another mine closure, privatization of State-owned mining companies, continued attempts to restart mining operations, a new fluorspar discovery, and relatively stable prices. In order of rank, China, Mexico, Mongolia, and South Africa were the major producers. *(See table 9.)*

Canada.—Burin Minerals Ltd. continued its efforts to reopen the fluorspar mining operations at St. Lawrence, Newfoundland. The company completed a first-stage private financing effort, was proceeding with efforts to arrange additional public equity financing, filled staff positions, confirmed size and grade of ore deposits, continued working with the Government on environmental requirements, and appointed a marketing agent (Burin Minerals Ltd., 1996).

Germany.—The Käfersteige fluorspar mine at Pforzheim and its flotation plant at Karlsruhe were closed down by Fluss-und-Schwerspatwerke Pforzheim GmbH, a subsidiary of Bayer AG. Mine production ceased at the end of September and mill production ceased at the end of October. Reasons given for the closure included competition from lower cost imports, the shrinking of the European fluorocarbon industry, and unfavorable currency exchange rates (Industrial Minerals, 1996a).

Kenya.—Kenya Fluorspar Co., Ltd., which has its mining operations in the Kerio Valley of Western Kenya, was privatized in 1996. The Kenyan Government, which owned 100% of Kenya Fluorspar, offered its entire stake in the company in a public tender. Nairobi-based Minerals and Chemicals Manufacturers Ltd. submitted the winning application (Industrial Minerals, 1996b).

Morocco.—As a result of a sales agreement with the Moroccan Government, Omnium Nord-Africain (ONA), through its holding company Managem, effectively increased its control of Société Anonyme d'Enterprises Minières (SAMINE) and its El Hammam fluorspar mine. The agreement called for ONA to increase to a majority stake its holdings in silver producer, SMI, which would then purchase the Government's 34% minority share in SAMINE (Industrial Minerals, 1996c).

Ukraine.—A new fluorspar deposit has reportedly been discovered in the Vinnitsa Region of Ukraine. Preliminary estimates of reserves put the deposit as second only to the Voskresenskoe deposit, largest in the Commonwealth of Independent States (Industrial Minerals in the CIS, 1996).

United Kingdom.—Production of acid-grade fluorspar increased by about 9% from 55,000 tons in 1995 to about 60,000 tons in 1996. Principal production came from Laporte Minerals with a smaller amount from Durham Industrial Minerals (formerly Weardale Fluorspar). The expected raw ore output from Deepwood Mining (as reported in the 1995 Annual Fluorspar Review) failed to materialize, but overall ore production from the Southern Pennine Orefield in Derbyshire did increase significantly with several new contributors in full production. This information was confirmed by P.L. Huxtable (Laporte Minerals, written commun., 1997).

Outlook

Consumption of acidspar by the chemical industry for the production of HF is the largest market for fluorspar. The largest use of HF is in the manufacture of fluorocarbons (CFC's, HCFC's, and HFC's), which accounts for about 65% to 70% of HF demand. It appears that demand for replacement fluorocarbons is slowly increasing, aided by the depletion of stocks of banned CFC's and by the crackdown of CFC smuggling into the United States. Unfortunately, increases in HF and HFC 134a capacity have out paced the slowly rising demand. Protracted low prices may result, especially for HFC 134a. Fluorspar demand by the AlF_3, steel, and other assorted markets is expected to remain at about current levels. It is expected that overall fluorspar demand will exhibit only small increases over the next few years.

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[1]Prior to January 1996, published by U.S. Bureau of Mines.

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TABLE 1
SALIENT FLUORSPAR STATISTICS 1/ 2/

		1992	1993	1994	1995	1996
United States:						
Production:						
Finished (shipments) e/ 3/	metric tons	51,000	60,000 r/	49,000	51,000	8,200
Value, f.o.b. mine	thousands	W	W	W	W	W
Exports 4/	metric tons	13,600	12,700	23,500	41,800	61,600
Value 5/	thousands	$1,980	$2,130	$3,690	$5,550	$8,110
Imports 6/	metric tons	534,000	497,000	492,000	558,000	513,000
Value 7/	thousands	$54,600	$47,000	$47,600	$67,400	$71,000
Value per ton, acid grade 7/		$106.71	$97.60	$97.66	$125.74	$141.56
Value per ton, metallurgical grade 7/		$84.72	$73.43	$74.88	$94.41	$103.00
Consumption (reported)	metric tons	485,000	447,000	486,000	534,000 r/	527,000
Consumption (apparent) 8/	do.	569,000	556,000	311,000 r/	446,000 r/	730,000
Stocks, December 31:						
Consumer and distributor	do.	75,400	78,000	284,000	405,000	234,000
Government stockpile	do.	1,180,000	1,160,000	909,000	756,000	667,000
World: Production	do.	4,120,000	4,090,000 r/	3,680,000 r/	4,050,000 r/	4,140,000 e/

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Does not include fluorosilicic acid (H2SiF6) or imports of hydrofluoric acid (HF) and cryolite.
3/ May include fluorspar from the National Defense Stockpile beneficiated by Ozark-Mahoning Co., IL.
4/ Source: Bureau of the Census and the U.S. Geological Survey.
5/ F.a.s. values at U.S. ports.
6/ Source: U.S. Bureau of the Census as modified by the U.S. Geological Survey.
7/ C.i.f. values at U.S. ports.
8/ U.S. primary and secondary production plus imports minus exports plus adjustments for Government and industry stock changes.
9/ Includes fluorspar purchased from the National Defense Stockpile, but still located at National Defense Stockpile depots.

TABLE 2
U.S. REPORTED CONSUMPTION OF FLUORSPAR, BY END USE 1/

(Metric tons)

	Containing more than 97% calcium fluoride (CaF_2)		Containing not more than 97% calcium fluoride (CaF_2)		Total	
End use or product	1995	1996	1995	1996	1995	1996
Hydrofluoric acid and aluminum fluoride	472,000 r/	477,000	--	--	472,000 r/	477,000
Basic oxygen furnaces	--	--	21,700	11,900	21,700	11,900
Electric furnaces	W	W	21,500	19,200	21,500	19,200
Other 2/	W	W	W	W	9,890 r/	18,800
Total	W	W	W	W	525,000	527,000
Stocks (consumer), December 31	89,900	106,000	2,530	11,100	92,400	17,500

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other" and/or in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes enamel, glass and fiberglass, iron and steel foundries, primary aluminum, primary magnesium, and welding rod coatings.

TABLE 3
PRICES OF IMPORTED FLUORSPAR

(Dollars per metric ton)

Source-grade	1995	1996
Mexican, f.o.b., Tampico:		
Acidspar filtercake	115-120	115-135
Metallurgical grade	85-95	80-105
South African, acidspar dry basis, F.o.b. Durban	100-115	125-135
U.S. Gulf port, dry basis, acidspar	142-152	142-152

Source: Industrial Minerals (Metal Bulletin PLC), No. 339, p. 64, Dec. 1995 and No. 351, p. 72, Dec. 1996.

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TABLE 4
U.S. EXPORTS OF FLUORSPAR, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/	1996 Quantity (metric tons)	1996 Value 2/
Bolivia	--	--	234	$33,900
Canada	21,900	$3,230,000	37,400	5,480,000
Dominican Republic	--	--	4,340	595,000
Italy	--	--	10,300	851,000
Korea, Republic of	1,830	204,000	540	84,800
Mexico	15,600	1,760,000	6,000	669,000
Taiwan	1,450	162,000	2,340	298,000
Venezuela	356	64,900	336	59,100
Other 3/	713 r/	128,000 r/	130	37,100
Total	41,800	5,550,000	61,600	8,110,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ F.a.s. values at U.S. ports.
3/ Includes Australia, Chile, Ecuador, France, Hong Kong, and the United Kingdom.

Source: Bureau of the Census.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR,
BY COUNTRY AND CUSTOMS DISTRICT 1/

Country and customs district	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Containing more than 97% calcium fluoride (CaF2):				
Austria: Charleston	--	--	348	$97
Canada: Detroit	19	$2	--	--
China:				
Houston 3/	170,000	22,400	212,000	29,300
New Orleans	149,000	18,000	144,000	21,900
Total	319,000	40,500	356,000	51,200
France: Philadelphia	182	96	54	28
Japan: Cleveland	88	11	--	--
Mexico:				
Laredo	20,400	2,720	18,100	2,530
New Orleans	10,700	957	--	--
Total	31,100	3,680	18,100	2,530
Morocco:				
Buffalo	114	32	--	--
Houston	5,940	731	--	--
New Orleans	18,000	2,590	--	--
Total	24,000	3,350	--	--
South Africa				
Houston	18,200	2,120	17,900	2,400
New Orleans	77,400	9,360	81,500	10,800
New York City	100	30	240	88
Ogdensburg	80	19	--	--
Total	95,800	11,500	99,600	13,300
Grand total	470,000	59,100	474,000	67,100
Containing not more than 97% calcium fluoride (CaF2):				
Canada:				
Buffalo	--	--	354	118
Ogdensburg	--	--	9	4
Total	--	--	363	122
China: New Orleans	15,100	1,570	--	--
Germany: New Orleans	--	--	194	20

See footnotes at end of table.

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TABLE 5--Continued
U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR,
BY COUNTRY AND CUSTOMS DISTRICT 1/

Country and customs district	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Containing not more than 97% calcium fluoride (CaF2)--Continued:				
Mexico:				
Baltimore	3,890	$494	--	--
Buffalo	1,620	191	--	--
El Paso	3,770	291	3,120	$238
Laredo	4,160	328	6,180	494
New Orleans	59,100	5,410	29,000	2,930
Norfolk	46	3	--	--
Total	72,600	6,710	38,300	3,660
Grand total	87,700	8,280	38,900	3,810

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C.i.f. values at U.S. ports.
3/ Includes data supplied by importer.

Source: Bureau of the Census, adjusted by the U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION
OF HYDROFLUORIC ACID (HF), BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Brazil	36	$35	--	--
Canada	112	269	105	$338
France	57	58	272	304
Germany	113	279	164	332
Japan	596	2,200	589	2,160
Mexico	69,400	63,100	81,200	75,700
Total	70,300	65,900	82,300	78,800

1/ Data are rounded to three significant digits, may not add to totals shown.
2/ C.i.f. values at U.S. ports.

Source: Bureau of the Census, adjusted by the U.S. Geological Survey.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION
OF CRYOLITE, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Australia	514	$129	--	--
Bahrain	--	--	1,010	$674
Canada	2,600	965	594	155
China	261	201	77	67
Denmark	205	230	296	427
Germany	2,190	2,220	2,070	2,400
Hungary	743	900	565	833
India	600	529	1,020	1,030
Italy	--	--	505	642
Other 3/	167 r/	159 r/	270	283
Total	7,270	5,330	6,400	6,510

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C.i.f. values at U.S. ports.
3/ Includes data for the Czech Republic, France, Japan, Mexico, Russia, Switzerland, and the United Kingdom.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION
OF ALUMINUM FLUORIDE, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Canada	2,660	$1,800	2,510	$2,410
France	--	--	900	1,030
India	--	--	309	312
Indonesia	--	--	1,500	1,510
Italy	2,430	1,830	129	96
Mexico	13,000	8,950	8,520	7,890
Norway	3,940	4,340	4,230	3,360
Other 3/	236 r/	266 r/	242	250
Total	22,200	17,200	18,300	16,800

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ C.i.f. values at U.S. ports.
3/ Includes data for Belgium, Germany, Japan, Sweden, and the United Kingdom.

Source: Bureau of the Census.

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TABLE 9
FLUORSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/ and grade 4/	1992	1993	1994	1995	1996 e/
Argentina	4,587	4,611	3,585 r/	5,071 r/	5,000
Brazil (marketable):					
Acid grade	61,432	68,325	68,890 r/	72,498 r/	36,000
Metallurgical grade	22,264	24,566 r/	21,041	16,860 r/	16,000
Total	83,696	92,891 r/	89,931 r/	89,358 r/	52,000
China: e/					
Acid grade	700,000	800,000	1,200,000 r/	1,200,000 r/	1,250,000
Metallurgical grade	1,200,000	1,300,000	800,000 r/	800,000 r/	900,000
Total	1,900,000	2,100,000	2,000,000 r/	2,000,000 r/	2,150,000
Czech Republic e/ 5/	XX	22,100 6/	10,000	15,000	15,000
Czechoslovakia 7/	40,000 e/	XX	XX	XX	XX
Egypt e/	1,700	773 6/	700	700	700
France: e/					
Acid and ceramic grades	118,000 6/	96,000	105,000	102,000 r/	80,000
Metallurgical grade	15,000 6/	20,000	26,000	28,000 r/	25,000
Total	133,000 6/	116,000	131,000	130,000 r/	105,000
Germany	53,100	40,000	37,000	39,000 e/	39,000
India:					
Acid grade	7,062	7,798	6,231 r/	4,875 r/	6,000
Metallurgical grade	13,572	13,846	16,360 r/	17,604 r/	17,000
Total	20,634	21,644	22,591 r/	22,479 r/	23,000
Iran e/ 8/	9,182 6/	10,000	10,000	10,000	10,000
Italy: e/					
Acid grade	55,000	35,000	52,630 r/ 6/	25,000	30,000
Metallurgical grade	25,000	25,000	15,312 r/ 6/	10,000	15,000
Total	80,000	60,000	67,942 r/ 6/	35,000	45,000
Kazakstan e/	100,000	90,000	80,000	80,000	80,000
Kenya: Acid grade	80,630	78,725	53,488 r/	80,230 r/	80,000
Korea, North: Metallurgical grade e/	41,000	41,000	40,000	40,000	40,000
Korea, Republic of: Metallurgical grade	70	50	50 e/	50 e/	50
Mexico: 9/					
Acid grade	189,000	187,000	129,000 r/	270,000	280,000
Metallurgical grade	95,000	93,000	103,000	252,000	260,000
Submetallurgical grade e/	3,000	3,000	3,000	--	--
Total	287,000 e/	283,000 e/	235,000 r/	522,000 r/	540,000
Mongolia:					
Acid grade	97,000	77,000	88,000	120,300	130,000 6/
Other grades 10/	287,000	276,000	85,000	119,000 r/ e/	124,000
Total	384,000	353,000	173,000	239,000 r/ e/	254,000
Morocco: Acid grade	85,500	70,050	85,000	105,800 r/	100,000
Namibia: Acid grade 11/	37,176	43,466	52,226	37,076 r/	20,000
Pakistan: Metallurgical grade	5,000 e/	5,100 e/	13,351 r/	2,753 r/	3,000
Romania: Metallurgical grade e/	15,000	15,000	15,000	15,000	15,000
Russia e/	100,000	70,000	60,000	60,000	60,000
South Africa: 12/					
Acid grade e/	230,000	195,000	166,761 6/	177,000	197,000
Ceramic grade e/	5,500	3,800	--	--	--
Metallurgical grade e/	22,600	19,000	7,497 6/	19,000	20,000
Total	258,105	217,778	174,258	195,866	217,000
Spain:					
Acid grade	94,000	82,000	97,000 r/ e/	96,000 r/ e/	95,000
Metallurgical grade e/	2,960 6/	5,000	10,000 r/	15,000 r/	10,000
Total e/	97,000 6/	87,000	107,000 r/	111,000 r/	105,000
Thailand:					
Acid grade	4,863	--	--	--	--
Metallurgical grade	51,597	48,387	23,705	24,114 r/	24,000
Total	56,460	48,387	23,705	24,114 r/	24,000
Tunisia: Acid grade	13,800	--	--	--	--
Turkey: Metallurgical grade	3,074	4,000 e/	6,671 r/	6,700 r/ e/	7,000
United Kingdom	76,100	70,300	58,000 e/	55,000 r/ e/	60,000
United States (shipments) e/	51,000	60,000	49,000	51,000	8,200
Uzbekistan e/	100,000	90,000	80,000	80,000	80,000
Grand total	4,120,000	4,090,000 r/	3,680,000 r/	4,050,000 r/	4,140,000

See footnotes at end of table.

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TABLE 9--Continued
FLUORSPAR: WORLD PRODUCTION, BY COUNTRY 1/ 2/

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 21, 1997.

3/ In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

4/ An effort has been made to subdivide production of all countries by grade (acid, ceramic, and metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.

5/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

6/ Reported figure.

7/ Dissolved Dec. 31, 1992.

8/ Year beginning Mar. 21 of that stated.

9/ Data are reported by Consejo de Recursos Minerales; but the production of submetallurgical grade and acid grade have been redistributed by the author based on industry data.

10/ Principally submetallurgical grade material.

11/ Data for 1993-96 are in wet tons.

12/ Data show estimated proportions of acid grade, ceramic grade, and metallurgical grade fluorspar within the reported totals.

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GALLIUM

By Deborah A. Kramer

The United States relied on imports of gallium to supply its domestic demand. France continued to be the largest supplier of gallium to the U.S. market. Most gallium was used to manufacture gallium arsenide (GaAs), which in turn, was used to produce optoelectronic devices and integrated circuits for commercial and military applications. Demand for gallium increased significantly in 1996, and domestic GaAs producers responded by increasing capacity to produce GaAs wafers. In addition to increasing capacity, some of the new facilities being constructed will be able to produce larger wafers, thereby reducing production costs.

Production

No production of primary gallium was reported in 1996. *(See table 1.)* Eagle-Picher Industries Inc. recovered and refined gallium from domestic and imported sources at its plant in Quapaw, OK. Recapture Metals Inc., Blanding, UT, recovered gallium from scrap materials, predominantly scrap generated during the production of GaAs. Recapture Metals' facilities have the capability of processing about 15 metric tons of high-purity gallium per year. The company recovers gallium from its customers' scrap on a fee basis and purchases scrap and low-purity gallium for processing to high-purity material.

Consumption

Optoelectronic devices continued to be the largest end use for gallium, with 59% of total consumption. Integrated circuits accounted for 40%, and the remaining 1% was used in research and development and other applications. *(See tables 2 and 3.)* The large increase in reported consumption of gallium in analog devices resulted from an adjustment in reporting by several firms.

Gallium data are collected by the U.S. Geologial Survey from two voluntary surveys of U.S. operations. In 1996, there were 16 responses to the "Consumption of Gallium" survey, representing 70% of the total canvassed. Significant quantities of gallium are used by universities and Government research facilities, which are not canvassed by the survey. In tables 1 through 3, data representing gallium consumption were adjusted to reflect full-industry coverage.

In March, M/A-COM Inc. produced a 22-kilogram, 100-millimeter-diameter single-crystalline structure GaAs ingot. The ingot was grown by the high-pressure, liquid-encapsulated Czochralski method using its proprietary large-melt process. This is one of the largest GaAs crystals grown commercially, and 400 wafers can be produced from an ingot this size. The ingot was remarkable because it was produced from a 24-kilogram melt. This type of increase in manufacturing efficiency has the potential to reduce costs to the customer (M/A-COM Inc., 1996).

Increased demand for GaAs resulted in several U.S. firms deciding to increase production capacity. TriQuint Semiconductor Inc. is constructing a new GaAs manufacturing facility and headquarters in Hillsboro, OR. The project, which is scheduled to be completed by March 1997, will include a 36,000-square-foot GaAs wafer fabrication unit incorporating 16,000 square feet of Class 100 clean room. TriQuint manufactures GaAs integrated circuits principally for analog applications in wireless telecommunications and computer systems (DPR Construction Inc., 1996). TriQuint also introduced two new manufacturing processes for its GaAs foundry customers. The principal advantages of the two new processes are a higher level of integrations (i.e., more components per wafer) and higher power throughput, up to 3 watts. Depending on the number of wafers purchased, costs for wafer processing by the new methods range from $2,800 to $5,200 per wafer (TriQuint Semiconductor Inc., 1996).

Anadigics Inc. also was constructing a new GaAs manufacturing facility near its Warren, NJ, headquarters. The expansion, which will renovate a vacant building, will have a new 10,000-square-foot clean room to process 4-inch wafers. This will nearly double Anadigics' GaAs wafer production capacity when the new capacity becomes operational in the fourth quarter of 1997. Although the equipment purchased for the facility will produce 4-inch wafers, it will be upgradable to process 6-inch wafers (Anadigics Inc., 1996).

In October, Vitesse Semiconductor Corp. began construction of a new GaAs integrated circuit manufacturing facility in Colorado Springs, CO. The new facility will be the first 6-inch GaAs very-large-scale integration production facility in the world and will have 100,000 square feet of manufacturing space. Total cost of the plant is estimated to be $75 million and will create 140 new jobs. Completion is scheduled for 1998. This is Vitesse's second GaAs manufacturing facility; the company operates a plant in Camarillo, CA (Vitesse Semiconductor Corp., 1996).

TRW Inc. installed a new multiwafer molecular beam epitaxy machine that can double the company's GaAs integrated circuit production capacity. The new machine can process either five 3-inch or three 4-inch GaAs wafers at one time, and the processing time for the five 3-inch wafers is the same as that for one 3-inch wafer on conventional equipment. Although the new equipment can produce epitaxial material for high-electron-mobility transistors and heterojunction bipolar transistors

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(HBT's), TRW is using the machine primarily to produce HBT's because of the high demand for HBT's in commercial wireless communication systems (TRW Inc., 1996).

Because the aluminum component of some laser diodes can oxidize in rising temperatures, attacking and degrading the laser cavity, scientists have developed aluminum-free laser diodes. Northwestern University granted an exclusive licence to Semiconductor Laser International Corp. (SLI), Endicott, NY, to develop, manufacture, and market aluminum-free semiconductor lasers. The manufacturing technique, developed at Northwestern, replaces aluminum with phosphorous or indium. Northwestern claims that the ion replacement will improve performance and increase power levels, leading to longer lived lasers. SLI expects to have the new lasers on the market in 1997 (Tatterson, 1996).

In Finland, researchers also have developed a method to produce aluminum-free laser diodes by substituting gallium indium arsenide phosphide (GaInAsP) for gallium aluminum arsenide (GaAlAs). The laser contains a layer of gallium indium arsenide between two layers of GaInAsP, and Tutcore, a commercial spin-off of the University of Tampere, claims that the laser can operate at twice the power output of conventional lasers with no loss of reliability (Walko, 1996).

Lidatek LLC, Mukilteo, WA, is marketing a line of consumer devices that the company claims operate as countermeasures to police laser speed guns. A silicon photodiode receiver detects incoming infrared light at a wavelength of about 900 nanometers, which then activates a GaAs laser diode that emits light at 904 nanometers, effectively jamming the laser radar gun (Photonics Spectra, 1996a).

Prices

Producer-quoted prices for gallium in 1996 did not change from those at yearend 1995. *(See table 4.)* By yearend 1996, traders reported that 99.9999%-pure gallium metal was being traded in the high $300's per kilogram, and 99.99%-pure gallium was in the low $300's per kilogram (Metal Bulletin, 1997).

Foreign Trade

U.S. gallium imports increased significantly in 1996. France (54%), Canada (20%), and Russia (11%) were the principal sources of imported gallium. *(See table 5.)* In addition to gallium metal, significant quantities of GaAs wafers were imported into the United States. A total of 4,940 kilograms of undoped GaAs wafers was imported in 1996, mostly from Japan. Japan (68%) and Canada (12%) were the main import sources for doped GaAs wafers, totaling 141,000 kilograms during the year.

World Review

Estimated crude gallium production was 55 tons in 1996; this was about a 10% decline from estimated production in 1995. Most of the decrease in production was from Russia and Kazakstan. Principal world producers were Australia, Germany, and Russia. Rhône-Poulenc S.A. continued to feed its purification facility in France from crude gallium produced at its 50-ton-per-year plant in Australia and from gallium produced in Germany. France, Japan, and the United States were the main world gallium refiners. *(See table 6.)*

Estimated imports of galliumin to Japan in 1996 were 41.7 tons, with France as the largest import source. Total gallium imports to Japan decreased significantly from the 1995 level of 58.3 tons, with the largest decrease in imports from France and Russia. The decline in imports from France was attributed to a rise in prices, and the decrease in imports from Russia was because of a decline in stocks (Roskill's Letter from Japan, 1997).

In early 1996, Dowa Mining Co. Ltd. began construction of a new plant to process rare-metal scrap, including gallium. The company plans to extract gallium, tantalum, and germanium dioxide from used semiconductors at the plant near Dowa's zinc smelter in Iijima. Dowa already operates a gallium purification plant in Hachioji and a gallium recycling plant near Kosaka. When the new plant became operational in April, Dowa's total gallium recycling capacity doubled to 10 tons per year (Metal Bulletin, 1996).

Current Research and Technology

Commercial development of blue lasers diodes based on gallium nitride (GaN) continue to fuel most research and development activities. The Japanese firm Nichia Kagaku Kogyo K.K. reportedly operated at blue-purple laser diode at room temperature; at 410 nanometers, the company claims the laser has the world's shortest wavelength for a semiconductor. The laser is made mostly of GaN, with some other materials that the company did not disclose. Potential applications for the new laser are in digital video disk players and compact disk players. If the laser can be used in compact disk players, then it could increase the recording density by four times over current technology (Photonics Spectra, 1996b). Toshiba Corp. also reported operating a GaN blue-purple laser at 417 nanometers at room temperature.

Scientists at the National Research Council of Canada produced a quantum dot laser that emits visible light. Until this development, quantum dot lasers only emitted light in the infrared region of the spectrum. The scientists sandwiched indium aluminum arsenide between two layers of GaAlAs in clusters of about 20 nanometers in diameter to create the quantum dot laser. One of the difficulties that must be addressed before commercial applications of these type of devices is the ability to grow a large number of the quantum dots and to assure that their sizes do not fluctuate by more that 10%; in a device this small, 10% corresponds to a difference of about 20 atoms (Wu, 1996).

Solarex reported a new record for solar efficiency with a copper indium gallium diselenide ($CuInGaSe_2$) thin film. The record, which was confirmed by the National Renewable Energy

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Laboratory, was 13% conversion efficiency. Solarex claimed that the combination of high efficiency and low cost places the $CuInGaSe_2$ material as a leading candidate for photovoltaic devices for bulk power generation (Troy, 1996).

Outlook

Gallium demand is expected to continue to grow in the United States, particularly for telecommunications applications. New GaAs production capacity being installed has the potential to enable production of GaAs devices at lower cost than by using current technology. A reduction in production costs will help to fuel the increase in demand. With an increase in demand, larger quantities of GaAs scrap will be generated, and this scrap most likely will be reprocessed and help to meet a portion of the demand. Although GaAs demand is expected to increase over the next few years, primary gallium demand will increase at a slightly slower rate.

In a report released by Strategies Unlimited, Mountain View, CA, the world market for short wavelength laser diodes in nontelecommunications applications was forecast to grow by 20% per year until 2000—from an estimated $486 million in 1995 to $1,238 million by 2000. This increase in demand will be driven by new digital video disk uses and high-speed CD-ROM uses. In addition, the study predicts that the blue-green laser diode, which is the focus of aggressive research, should appear in high-density storage applications by 2000 (Lasers & Optronics, 1996).

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TABLE 1
SALIENT U.S. GALLIUM STATISTICS 1/

(Kilograms unless otherwise specified)

	1992	1993	1994	1995	1996
Production	--	--	--	--	--
Imports for consumption	8,480	15,600	16,900	18,100	30,000
Consumption	10,600	11,300	15,500	16,900	21,900
Price per kilogram	$425	$400	$395	$425	$425

1/ Data are rounded to three significant digits.

TABLE 2
U.S. CONSUMPTION OF GALLIUM, 1/ BY END USE 2/

(Kilograms)

End use	1995	1996
Optoelectronic devices:		
Laser diodes and light-emitting diodes	13,700	11,600
Photodetectors and solar cells	1,120	1,280
Integrated circuits:		
Analog	1,610	8,200
Digital	355	623
Research and development	59	184
Other	94	38
Total	16,900	21,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes gallium metal and gallium compounds.

TABLE 3
STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, 1/ BY GRADE 2/

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1995:				
99.99% to 99.999%	360	589	92	857
99.9999%	315	11,400	11,100	532
99.99999% to 99.999999%	459	5,260	5,660	55
Total	1,130	17,200	16,900	1,440
1996:				
99.99% to 99.999%	857	39	462	434
99.9999%	532	8,970	9,080	422
99.99999% to 99.999999%	55	13,300	12,300	1,020
Total	1,440	22,300	21,900	1,880

1/ Consumers only.
2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 4
YEAREND GALLIUM PRICES

(Dollars per kilogram)

Gallium metal, 99.999999%-pure, 100-kilogram lots	$525
Gallium metal, 99.99999%-pure, 100-kilogram lots	425
Gallium metal, 99.9999%-pure, 100-kilogram lots	390
Gallium metal, 99.9999%-pure, imported	$380- 425
Gallium oxide, 99.99%-pure, imported	275- 350

Source: American Metal Market.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF GALLIUM 1/
(UNWROUGHT, WASTE AND SCRAP), BY COUNTRY

(Kilograms)

	1995		1996	
Country	Quantity	Value	Quantity	Value
Canada	837	$262,000	5,900	$1,590,000
France	11,300	3,040,000	16,300	5,360,000
Hungary	370	60,200	493	128,000
Japan	260	77,400	1,310	164,000
Netherlands	--	--	1,500	578,000
Russia	4,600	782,000	3,360	1,240,000
United Kingdom	114	21,200	25	13,500
Other	635 r/	101,000 r/	1,120	364,000
Total	18,100	4,350,000	30,000	9,440,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 6
WORLD ANNUAL PRIMARY GALLIUM
PRODUCTION CAPACITY, 1/ DECEMBER 31, 1996

(Metric tons)

Continent and country	Capacity
North America: United States 2/	3
Europe:	
France	20
Germany	20
Hungary	4
Slovakia	3
Former U.S.S.R. e/	30
Total	77
Asia:	
China	8
Japan	7
Total	15
Oceania: Australia	50
World total	145

e/ Estimated.
1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Standby capacity as of Dec. 31, 1996.

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GARNET

By Ronald F. Balazik

Garnets are a complex family of silicate minerals with similar crystalline structures and a wide range of chemical compositions and properties. The general chemical formula for garnet is $A_3B_2(SiO_4)$, where A can be calcium, magnesium, ferrous iron, or manganese; and B can be aluminum, chromium, ferric iron, or titanium. Much industrial-grade garnet from the United States is a solid solution of almandine (iron-aluminum garnet) and pyrope (magnesium-aluminum garnet) that breaks into sharp chisel-edged plates. Industry uses garnet as an abrasive material (6.5 to 9.0 Mohs hardness range). Low-quality industrial garnet primarily is utilized as airblasting or hydroblasting media and as filtration media.

Production

It is estimated that the United States accounts for more than one-third of world industrial garnet production. In 1996, six U.S. firms, including a new company, produced 68,200 tons of crude garnet concentrate valued at about $10.2 million. The firms were Barton Mines Corp., Warren County, NY; NYCO Minerals, Inc., Essex County, NY; Patterson Materials Corp., Wingdale, NY; International Garnet Abrasive Inc., Clinton County, NY; Emerald Creek Garnet Co., Benewah County, ID; and Cominco American Inc., Madison County, MT (a new producer). All six companies were surveyed by the U.S. Geological Survey to determine U.S. production and sales of industrial garnet. Five of the six companies responded to the survey; production at the remaining firm was estimated.

The new Cominco American mine cited above opened in early 1996. The facility reportedly will produce almandine garnet at a rate of about 9,000 tons annually, but eventually will expand to a capacity of 40,000 tons per year.

Also in 1996, Western Garnet International (owner of the Emerald Creek operation noted above) and NYCO Minerals signed an agreement under which Western has the right to purchase garnet from NYCO.

Consumption

The United States is the world's largest consumer of industrial garnet. It is estimated that U.S. consumption of industrial garnet was about 50,000 tons in 1996. According to various reports, domestic use of industrial garnet accounted for 25% to 40% of global consumption in the mid-1990's (Gorrill, 1996; Roskill, 1996). Major end uses in the United States and their estimated market share are as follows: Blasting media, 45%; water filtration, 15%; waterjet cutting, 10%; and abrasive powders, 10%. (Gorrill, 1996). Domestic industrial sectors that utilize garnet include the petroleum industry, filtration systems, aircraft and motor vehicle manufacturers, wood furniture finishing operations, electronic component manufacturing, and ceramics and glass production.

Industrial garnet is used primarily as a loose-grain abrasive; some lower quality industrial garnet also is used as filtration media. High-quality, high-value garnet primarily has been used as a loose-grain abrasive for applications such as optical lens grinding and plate-glass grinding for more than a century. In recent years, industrial garnet has been used for high-quality, scratch-free lapping of semiconductor materials and other metals. Other industrial applications include the manufacture of coated abrasives; air/water blasting; hydrocutting; nonskid surfaces; and the finishing of wood, leather, hard rubber, felt, and plastics.

Shipbuilding and aluminum aircraft industries use lower quality garnet for sandblasting. Similar uses include the cleaning and conditioning of aluminum and other soft metals as well as metals cleaning by structural steel fabrication shops. Mixed-media water filtration, using a mixture of sand, anthracite, and garnet, has displaced older filtration methods because it is more reliable and provides better water quality. Garnet entrained in high-pressure streams of water also is used to cut many different materials. The manufacturers of nonskid floor paint also use alluvial and other lower cost garnets in their products.

Garnet has an intermediate place in the coated-abrasive field between lower cost quartz sand and more costly synthetic abrasives (silicon carbide and fused alumina). In addition, garnet reportedly is more efficient than quartz sand in similar applications. However, garnet, especially the lower grades, cannot compete with synthetic abrasives in most metalworking applications requiring substantial metal removal because of its friable nature and lower hardness.

Prices

Industrial garnet has a very wide range of prices that are dependent on type, source, quantity purchased, quality, and application. Reported values for crude concentrates in 1996 averaged $150 per ton, but ranged from about $20 to $190 per ton. Refined garnet values generally ranged from $160 to $350 per ton (Industrial Minerals, 1996). However, prices for small quantities of highly processed garnet (e.g., powders) that are more than double the upper limit of this range have been reported.

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Foreign Trade

The U.S. Department of Commerce, which is the major government source of U.S. trade data, does not provide import or export statistics on industrial garnet. However, the U.S. Geological Survey estimates that U.S. industrial garnet imports and exports in 1996 were 8,000 tons and 13,000 tons, respectively. Australia has accounted for about 85% of U.S. industrial garnet imports since 1990; China and India have been the remaining import sources.

World Review

Garnet occurs worldwide in many metamorphic rocks, particularly gneisses and schists. Moreover, garnet occurs as contact-metamorphic deposits in crystalline limestones, pegmatites, and serpentinites, and in high-temperature intrusive contacts and vein deposits. Alluvial garnet also is a coproduct with many heavy mineral sand and gravel deposits throughout the world. In addition to the United States, major garnet deposits exist in Australia, China, and India, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets.

Estimates of world industrial garnet production range from 145,000 to more than 200,000 tons. In addition to the United States, leading producers in recent years have been Australia, China, and India. Estimates of Australian production in the mid-1990's have ranged from 30,000 tons to about 70,000 tons; estimates for India have been between 15,000 and 60,000 tons. Chinese output of industrial garnet during the same period reached at least 15,000 tons. At yearend 1996, significant new garnet operations were under development in southeastern India and in Ontario, Canada.

Outlook

Forecasts indicate significant growth in world demand for industrial garnet; one report projects an average annual increase of 7% during the next 10 years (Roskill, 1996). These forecasts predict that global markets for industrial garnet may increase by more than 160,000 tons within the next 5 years. Specifically, world markets for garnet blasting media and waterjet cutting conceivably could more than double by the year 2000 if economic conditions permit. Planned production worldwide to meet anticipated demand would add at least 160,000 tons of capacity if constructed. This new capacity would tend to restrain price increases.

According to industry plans, U.S. production capacity for garnet could increase significantly before the end of this decade. However, the domestic garnet industry may be operating near capacity already. If so, new domestic markets for industrial garnet in the remaining 1990's largely will depend on imports if economic conditions and/or resource restrictions delay additional capacity.

If industrial garnet is not available to meet growing demand, other natural and synthetic abrasives could serve as substitutes to some extent for all major end uses. In many cases, however, the substitutes would entail sacrifices in quality or cost. Fused alumina and staurolite compete with garnet as a sandblasting material in the transportation equipment industries. Ilmenite and plastics compete as filtration media. Diamond, corundum, and fused alumina compete for lens grinding and for many lapping operations. Finally, sand, silicon carbide, and fused alumina compete for grinding and finishing of plastics, wood furniture, and other products.

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TABLE 1
SALIENT U.S. INDUSTRIAL GARNET STATISTICS 1/

	Crude production		Sold or used	
Year	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1992	54,100	$4,840	46,100	$13,000
1993	44,000	4,440	55,800	15,400
1994	51,000	6,100	51,100 r/	13,000 r/
1995	53,000	9,690 r/	46,100 r/	11,100 r/
1996	68,200	10,200	58,500	12,200

r/ Revised.
1/ Data are rounded to three significant digits.

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GEMSTONES

By Ronald F. Balazik

According to Webster's dictionary, a gem is "any jewel, whether stone, pearl or the like, having value and beauty that are intrinsic and not derived from its setting; a precious or, sometimes, a semiprecious stone cut and polished for ornament. A semiprecious stone of value because it is carved or engraved, as a cameo or intaglio." Additionally, the dictionary states that gemstone is "any mineral or petrified material which can, when cut and polished, be used in jewelry."

For this report, therefore, "gemstone" is defined as any organic or inorganic mineral used for personal adornment, display, or object of art because the mineral possesses beauty, rarity, and durability. Note that shell and cultured pearl are treated as gemstones in this report. Also, synthetic gems are covered in this report but are treated separately from natural gemstones. *(See tables 1 and 2.)*

Production

It is estimated that the value of natural gemstones produced in the United States from indigenous sources during 1996 was at least $44 million. *(See table 3.)* This output was significantly less than production in the preceding year because foreign markets for shell declined, particularly in Japan where the operations of cultured pearl producers who use shell material for pearl nuclei were adversely affected by massive pearl oyster deaths.

The estimate of 1996 gemstones production is based on a survey of more than 250 domestic gemstone operations conducted by the U.S. Geological Survey (USGS). The survey provides a foundation for projecting the scope and level of domestic gemstone production. However, the survey does not represent all gemstone activity in the United States, which includes thousands of professional and amateur collectors. Consequently, the USGS attempts to supplement its survey with estimates of domestic gemstones production from related published data, contacts with gem dealers and collectors, and analyses of gem and mineral shows.

Natural gem materials indigenous to the United States are collected, produced, or marketed in every State. However, six States accounted for more than 75% of the total value of production reported by survey respondents. These States (in declining order of reported production value) were Tennessee, Oregon, Kentucky, Arkansas, Arizona, and Alabama. Certain States are known best for the production of a single gem material (e.g., Tennessee for freshwater shell). Other States, however, have a wide array of gemstones. For example, Arizona gemstone deposits include agate, amethyst, azurite, chrysocolla, fire agate, garnets, jade, malachite, obsidian, onyx, petrified wood, precious opal, smithsonite, and turquoise. A great variety of gemstones also can be found in California, Idaho, Montana, and North Carolina.

Progress continued in 1996 toward opening the first commercial diamond mine in North America in almost a century. Colorado Diamond Co., a subsidiary of Redaurum Red Lakes Mines Ltd. (Toronto), announced a two-year trial mining program at its Kelsey Lake kimberlite prospect near Fort Collins, CO (U.S. Geological Survey 1997b). Open pit mining at Kelsey Lake commenced in 1995, and a diamond processing plant at the site began operating in May 1996. Production is expected to reach 100,000 to 150,000 carats at its peak.

Evaluation of a large lamproite intrusion located in Crater of Diamonds State Park near Murfreesboro, AR, also continued in 1996 (U.S. Geological Survey, 1997a). The intrusion has long been known to contain diamonds that range greatly in size and quantity. During 1996, the U.S. National Park Service permitted Arkansas to proceed with bulk sampling and testing operations.

In addition to natural gemstones, laboratory-grown synthetic gems and gem simulants are produced in the United States and elsewhere. Synthetic gemstones essentially have the same appearance and the same optical, physical, and chemical properties as the natural materials that they represent. Simulants have an appearance similar to that of a natural gem material but have different optical, physical, and chemical properties. Synthetic gemstones produced in the United States include alexandrite, emerald, ruby, sapphire, turquoise, and zirconia. Simulants produced in the United States include coral, cubic zirconia, lapis lazuli, malachite, and turquoise. Additionally, certain colors of synthetic sapphire and spinel, used to represent other gemstones, are classed as simulants. Colored and colorless varieties of cubic zirconia are the major simulants produced.

Synthetic gem production in the United States reached $24 million in 1996; simulant gemstone output was even greater (estimated to exceed $100 million). Five firms in four states, representing virtually all of the U.S. synthetic gem industry, reported production to the USGS in 1996. In descending order of production value, the States with reported output were California, New York, Michigan, and Arizona.

Consumption

The U.S. market in 1996 for natural, unset colored gemstones (excluding pearl and coral) was estimated to be more than $370 million. The domestic market for unset gem diamonds in 1996 was estimated to be more than $4.3 billion, the largest in the world.

Gemstones are used in the United States and elsewhere for

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jewelry, collections/exhibits, decorative art objects, and certain industrial applications. According to a poll conducted in 1996 by a U.S. jewelry retailers association, 61% of domestic consumers who were surveyed preferred diamond as their favorite gemstone; others preferred emeralds (10%), sapphires (9%), and rubies (7%) (International Colored Gemstone Association, 1996).

Prices

Gemstone prices are governed by many factors, including beauty, clarity, defects, demand, and rarity. Values and prices of gemstones produced and/or sold in the United States are shown in tables 3 through 5. In addition, customs values for diamonds and other gemstones imported and exported or reexported are shown in tables 6 through 10.

The Central Selling Organization (CSO), controlled by De Beers Centenary AG (Switzerland), is a significant force affecting gem diamond prices worldwide. The average price of all rough uncut diamonds sold worldwide was estimated to be about $70 per carat in 1996; by country, the average value reported per carat ranged from $9 for Australian production to $315 for Namibian output (Financial Times, 1997).

Foreign Trade

By several standards, the United States is the world leader in gemstone trade. In 1996, U.S. gemstone imports came from 106 countries and domestic exports/reexports of gemstones went to 56 countries. *(See tables 6 through 10.)*

The United States remained the world's largest importer of colored gemstones in 1996; imports of natural colored gemstones, excluding coral and pearl, reached $572 million. During the year, U.S. imports of all gemstones, including synthetics and simulants, increased 8% to a record high of $7.24 billion. Gem diamonds accounted for about 90% of the total.

Domestic exports and reexports of all gemstones in 1996 totaled about $2.7 billion; diamonds, including $2.2 billion for cut diamonds, accounted for 81% of the total. The value of U.S. exports plus reexports of natural, rough, colored gemstones was about $29.1 million, while the value of U.S. exports plus reexports of natural, cut, colored gemstones was about $175 million. Synthetic gemstone exports and reexports during the year were valued at $12.4 million and $17.1 million, respectively. Exports and reexports of pearl were valued at $1.9 million and $6.6 million, respectively. Approximately $38.6 million of coral and shell was exported and reexported by the United States in 1996.

World Review

In 1996, world diamond production reached 117 million carats with an estimated value of approximately $7 billion. *(See table 11.)* Although there are many diamond mines throughout the world, much production is concentrated in a few regions. Most world diamond production occurs in Africa (Angola, Botswana, Namibia, South Africa, and Zaire); Asia (northeastern Siberia and Yakutia in Russia); Australia; and South America (Brazil and Venezuela).

In addition to the new U.S. diamond mine, noted on page 1, substantial progress was made in 1996 on plans for Canada's first gem-quality diamond mine (Wilkinson, 1997). Final approvals for construction of the mine, located in the Northwest Territories, were granted during the year by the Canadian government. The mine is expected to employ 800 workers and generate approximately $350 million annually over a 25-year lifespan. Production is scheduled to begin in 1998.

De Beers Centenary AG, through its CSO, controlled most of the rough, uncut diamonds sales worldwide during 1996. De Beers reported record sales of $4.83 billion during the year. The record was 7% greater than De Beers rough diamond sales in 1995. Moreover, the sales in 1996, unlike the preceding 2 years, surpassed the value of diamond stocks ($4.7 billion) held by De Beers (Cockle, 1997b). Nevertheless, world diamond retail sales decreased slightly to $52 billion, partly due to a weaker Japanese market (Cockle, 1997a).

De Beers also encountered significant events in the world diamond market during 1996. For example, Australia's Argyle Diamond Mines Joint Venture (which accounts for more than one-third of global diamond output) withdrew from the CSO to sell its production independently. In addition, Russia's marketing accord with the CSO was not renewed when agreement on the terms of a new contract could not be reached; negotiations between the two parties were continuing at yearend.

It is estimated that annual world production of cut natural gemstones other than diamond and pearl exceeded $2 billion in the mid-1990's. Foreign countries with major gemstone deposits other than diamond are Afghanistan (beryl, ruby, and tourmaline); Australia (beryl, opal, and sapphire); Brazil (agate, amethyst, beryl, ruby, sapphire, topaz, and tourmaline); Burma (beryl, jade, ruby, sapphire, and topaz); Colombia (beryl, emerald, and sapphire); Kenya (beryl, garnet, and sapphire); Madagascar (beryl, rose quartz, sapphire, and tourmaline); Mexico (agate, opal, and topaz); Sri Lanka (beryl, ruby, sapphire, and topaz); Tanzania (garnet, ruby, sapphire, tanzanite, and tourmaline); and Zambia (amethyst and beryl). The world's largest blue sapphire (90,000 carats) reportedly was discovered in Madagascar during 1996 (Unpub. data accessed June 18, 1997, on the World Wide Web at URL http://www.gemstone.org/source.html).

Outlook

Trends toward the growth of personal disposable income, particularly in industrialized and developing nations, will continue to be the principal influence on world demand for precious gems. In addition, the independence displayed by major diamond producers in 1996 vis-a-vis the De Beers CSO may prove to be an important new trend in world diamond markets; however, its significance cannot be assessed at present.

Asian nations such as Japan and others with growing personal wealth are expected to be the most rapidly expanding

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markets for precious gems, particularly diamond. One indicator of this trend is that China will open its first diamond exchange and recently liberalized its investment policy for foreign jewelry manufacturers to allow more sales within the country (Henricus, 1997; Schlussel, 1997).

Demand for colored gemstones will continue to rise as diamonds become more expensive and promotional efforts by retailers promote the popularity of alternatives. The retail jewelry trade will further consolidate toward fewer companies while more dealers focus on niche markets and target specific demographic groups. Greater demand for synthetic and simulant gemstones also is anticipated.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Amber	Hydrocarbon	Yellow, red, green, blue	Any	Low to medium	2.0-2.5	1.0-1.1	Single	1.54	Synthetic or pressed plastics	Fossil resin, soft.
Beryl:										
Aquamarine	Beryllium aluminum silicate	Blue-green to light blue	do.	Medium to high	7.5-8.0	2.63-2.80	Double	1.58	Synthetic spinel, blue topaz	Double refraction, refractive index.
Bixbite	do.	do.	Small	Very high	7.5-8.0	2.63-2.80	do.	1.58	Pressed plastics, tourmaline	Refractive index.
Emerald	do.	Green	Medium	do.	7.5	2.63-2.80	do.	1.58	Fused emerald, glass, tourmaline, peridot, green garnet doublets	Emerald filter, dichroism, refractive index.
Emerald, synthetic	do.	do.	Small	High	7.5-8.0	2.63-2.80	do.	1.58	Genuine emerald	Flaws, brilliant, fluorescence in ultraviolet light.
Golden (heliodor)	do.	Yellow to golden	Any	Low to medium	7.5-8.0	2.63-2.80	do.	1.58	Citrine, topaz, glass, doublets	
Goshenite	do.	do.	do.	Low	7.5-8.0	2.63-2.80	do.	1.58	Quartz, glass, white sapphire, white topaz.	Refractive index.
Morganite	do.	Pink to rose	do.	do.	7.5-8.0	2.63-2.80	do.	1.58	Kunzite, tourmaline, pink sapphire	Do.
Calcite:										
Marble	Calcium carbonate	White, pink, red, blue, green, or brown	do.	do.	3.0	2.72	Double (strong)	1.49-1.66	Silicates, banded agate, alabaster gypsum	Translucent.
Mexican onyx	do.	do.	do.	do.	3.0	2.72	do.	1.6	do.	Banded, translucent.
Chrysoberyl:										
Alexandrite	Beryllium aluminate	Green by day, red by artificial light	Former U.S.S.R. (small), Sri Lanka (medium)	High	8.5	3.50-3.84	Double	1.75	Synthetic	Dichroism, inclusions in synthetic sapphire.
Cats-eye	do.	Greenish to brownish	Small to large	do.	8.5	3.50-3.84	do.	1.75	Synthetic, shell	Gravity and translucence.
Chrysolite	do.	Yellow, green, and/or brown	Medium	Medium	8.5	3.50-3.84	do.	1.75	Tourmaline, peridot	Refractive index, silky.
Coral	Calcium carbonate	Orange, red, white, black, or green	Branching, medium	Low	3.5-4.0	2.6-2.7	do.	1.49-1.66	False coral	Dull translucent.

See footnotes at end of table.

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TABLE 1--Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Corundum:										
Ruby	Aluminum oxide	Rose to deep purplish red	Small	Very high	9.0	3.95-4.10	Double	1.78	Synthetics, including spinel	Inclusions, fluorescence.
Sapphire	do.	Blue	Medium	High	9.0	3.95-4.10	do.	1.78	do.	Inclusions, double refraction, dichroism.
Sapphire, fancy	do.	Yellow, pink, white, orange, green, or violet	Medium to large	Medium	9.0	3.95-4.10	do.	1.78	Synthetics, glass and doublets	Inclusions, double refraction, refractive index.
Sapphire and ruby stars	do.	Red, pink, violet, blue, or gray	do.	High to low	9.0	3.95-4.10	do.	1.78	Star quartz, synthetic stars	Shows asterism, color side view.
Sapphire or ruby synthetic	do.	Yellow, pink, or blue	Up to 20 carats	Low	9.0	3.95-4.10	do.	1.78	Synthetic spinel, glass	Curved striae, bubble inclusions.
Diamond	Carbon	White, blue-white, yellow, brown, green, pink, blue	Any	Very high	10.0	3.516-3.525	Single	2.42	Zircon, titania, cubic zirconia	High index, dispersion, single refraction hardness, cut, luster.
Feldspar:										
Amazonite	Alkali aluminum silicate	Green	Large	Low	6.0-6.5	2.56	--	1.52	Jade	Cleavage, sheen, vitreous to pearly, opaque, grid.
Labradorite	do.	Gray with blue and bronze sheen color play	do.	do.	6.0-6.5	2.56	--	1.56	do.	Do.
Moonstone	do.	White	do.	do.	6.0-6.5	2.77	--	1.52-1.54	Glass or white onyx	Blue sheen, opalescent.
Garnet	Complex silicate	Brown, black, yellow, green, ruby red, or orange	Small to medium	Low to high	6.5-7.5	3.15-4.30	Single strained	1.79-1.98	Synthetics, spinel, glass	Single refraction, anomalous strain.
Jade:										
Jadeite	do.	Green, yellow, black, white, or mauve	Large	Low to very high	6.5-7.0	3.3-3.5	Cryptocrystalline	1.65-1.68	Onyx, bowenite, vesuvianite, grossularite	Luster, spectrum, translucent, to opaque.
Nephrite	Complex hydrous silicate	do.	do.	do.	6.0-6.5	2.96-3.10	do.	1.61-1.63	do.	Do.
Opal	Hydrous silica	Colors flash in white gray, black, red, or yellow	Large	Low to high	5.5-6.5	1.9-2.3	Isotropic	1.45	Glass, synthetics, triplets	Play of color.
Pearl	Calcium carbonate	White, pink, or black	Small	do.	2.5-4.0	2.6-2.85	--	--	Cultured and imitation	Luster, structure, X-ray.
Peridot	Iron magnesium silicate	Yellow and/or green	Any	Medium	6.5-7.0	3.27-3.37	Double (strong)	1.65-1.69	Tourmaline chrysoberyl	Strong double refraction, low dichroism.

See footnotes at end of table.

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TABLE 1--Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size 1/	Cost 2/	Mohs	Specific gravity	Refraction	Refractive index	May be confused with-	Recognition characters
Quartz:										
Agate	Silica	Any color	Large	Low	7.0	2.58-2.64	--	--	Glass, plastic, Mexican onyx	Cryptocrystalline, irregularly banded, dendritic inclusions.
Amethyst	do.	Purple	do.	Medium	7.0	2.65-2.66	Double	1.55	do.	Refractive index, double refraction, transparent.
Cairngorm	do.	Smoky	do.	Low	7.0	2.65-2.66	do.	1.55	do.	Do.
Citrine	do.	Yellow	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Do.
Crystal, rock	do.	Colorless	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Do.
Jasper	do.	Uniform or spotted red, yellow, or green	do.	do.	7.0	2.58-2.66	--	--	do.	Opaque, vitreous.
Onyx	do.	Many colors	do.	do.	7.0	2.58-2.64	--	--	do.	Uniformly banded.
Rose	do.	Pink, rose red	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Refractive index, double refraction, translucent.
Spinel	Magnesium aluminum oxide	Any	Small to medium	Medium	8.0	3.5-3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	do.	Up to 40 carats	Low	8.0	3.5-3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubbles.
Spodumene:										
Hiddenite	Lithium aluminum silicate	Yellow to green	Medium	Medium	6.5-7.0	3.13-3.20	do.	1.66	Synthetic spinel	Refractive index.
Kunzite	do.	Pink to lilac	do.	do.	6.5-7.0	3.13-3.20	do.	1.66	Amethyst, morganite	Do.
Tanzanite	Complex silicate	Blue	Small	High	6.0-7.0	3.30	do.	1.69	Sapphire, synthetics	Strong trichroism.
Topaz	do.	White, blue, green	Medium	Low to medium	8.0	3.4-3.6	do.	1.62	Beryl, quartz	Refractive index.
Tourmaline	do.	All, including mixed	do.	do.	7.0-7.5	2.98-3.20	do.	1.63	Peridot, beryl, corundum, glass	Double refraction, refractive index.
Turquoise	Copper aluminum phosphate	Blue to green	Large	Low	6.0	2.60-2.83	do.	1.63	Glass, plastics	Difficult if matrix not present, matrix usually limonitic.
Zircon	Zirconium silicate	White, blue, or brown, yellow, or green	Small to medium	Low to medium	6.0-7.5	4.0-4.8	Double (strong)	1.79-1.98	Diamond, synthetics, topaz, aquamarine	Double refraction, strongly dichroic, wear on facet edges.

1/ Small-up to 5 carats; medium-up to 50 carats; large-more than 50 carats.
2/ Low-up to $25 per carat; medium-up to $200 per carat; high-more than $200 per carat.

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TABLE 2
SYNTHETIC GEMSTONE PRODUCTION METHODS

Gemstone	Production methods	Company/producer	Date of first production
Alexandrite	Flux	Creative crystals	1970's
Do.	Melt pulling	J.O. Crystal	1990's
Do.	do.	Kyocera	1980's
Do.	Zone melt	Seiko	1980's
Cubic zirconia	Skull melt	Various producers	1970's
Emerald	Flux	Chatham	1930's
Do.	do.	Gilson	1960's
Do.	do.	Kyocera	1970's
Do.	do.	Seiko	1980's
Do.	do.	Lennix	1980's
Do.	do.	Russia	1980's
Do.	Hydrothermal	Lechleitner	1960's
Do.	do.	Regency	1980's
Do.	do.	Biron	1980's
Do.	do.	Russia	1980's
Ruby	Flux	Chatham	1950's
Do.	do.	Kashan	1960's
Do.	do.	J.O. Crystal (Ramaura)	1980's
Do.	do.	Douras	1990's
Do.	Zone melt	Seiko	1980's
Do.	Melt pulling	Kyocera (Inamori)	1970's
Do.	Verneuil	Various producers	1900's
Sapphire	Flux	Chatham	1970's
Do.	Zone melt	Seiko	1980's
Do.	Melt pulling	Kyocera	1980's
Do.	Verneuil	Various producers	1900's
Star ruby	do.	Linde (Div. of Union Carbide)	1940's
Do.	Melt pulling	Kyocera	1980's
Do.	do.	Nakazumi	1980's
Star sapphire	Verneuil	Linde	1940's

TABLE 3
VALUE OF U.S. GEMSTONE PRODUCTION, BY GEMSTONE 1/

(Thousand dollars)

Gem materials	1995	1996
Agate	907	1,110
Beryl	698	960
Coral (all types)	114	152
Diamonds	163	685
Garnet	54 r/	40
Gem feldspar	3,150	4,980
Geode/nodules	206	169
Obsidian	64	64 e/
Opal	475	363
Peridot	225	--
Petrified wood	150	54 e/
Quartz	1,440	1,880
Sapphire/ruby	4,910 r/	2,030
Shell	29,000 r/	22,800
Topaz	9	14
Tourmaline	52	25
Turquoise	1,670	1,410
Other	5,410 r/	6,900
Total	48,700 r/	43,600

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 4
PRICES OF U.S. CUT DIAMONDS, BY SIZE AND QUALITY 1/

Carat weight	Description, color 2/	Clarity 3/ (GIA terms)	Representative prices		
			January 1996 4/	August 1996 5/	December 1996 6/
0.25	G	VS1	$1,400	$1,400	$1,500
.25	G	VS2	1,300	1,280	1,380
.25	G	SI1	975	1,030	1,130
.25	H	VS1	1,300	1,300	1,400
.25	H	VS2	1,150	1,150	1,250
.25	H	SI1	950	950	1,050
.50	G	VS1	3,050	3,200	3,300
.50	G	VS2	2,700	2,800	2,900
.50	G	SI1	2,400	2,300	2,500
.50	H	VS1	2,800	2,800	2,900
.50	H	VS2	2,600	2,500	2,600
.50	H	SI1	2,300	2,200	2,400
.75	G	VS1	3,600	3,600	3,800
.75	G	VS2	3,350	3,400	3,600
.75	G	SI1	3,100	3,100	3,300
.75	H	VS1	3,400	3,450	3,650
.75	H	VS2	3,200	3,250	3,450
.75	H	SI1	2,900	2,900	3,100
1.00	G	VS1	4,900	5,200	5,400
1.00	G	VS2	4,600	4,900	5,200
1.00	G	SI1	4,200	4,400	4,700
1.00	H	VS1	4,500	4,800	5,000
1.00	H	VS2	4,400	4,700	4,900
1.00	H	SI1	4,000	4,200	4,500

1/ Data are rounded to three significant digits.
2/ Gemological Institute of America (GIA) color grades: D--colorless; E--rare white; G - H - I --traces of color.
3/ Clarity: IF--no blemishes; VVS1--very, very slightly included; VS1--very slightly included; VS2--very slightly included, but not visible; SI1--slightly included.
4/ Jewelers' Circular-Keystone. V. 167, No. 3, Mar. 1996, p. 142.
5/ Jewelers' Circular-Keystone. V. 167, No. 9, Sept. 1996, p. 222.
6/ Jewelers' Circular-Keystone. V. 168, No. 1, Jan. 1997, p. 290.

TABLE 5
PRICES OF U.S. CUT COLORED GEMSTONES, BY SIZE 1/

Gemstone	Carat weight	Price range per carat	
		January 1996 2/	December 1996 2/
Amethyst	1	$8 -$18	$7 - $16
Aquamarine	1	75-90	75 - 190
Emerald	1	1,750 - 3,200	1,575 - 2,900
Garnet, tsavorite	1	600 - 900	600 - 900
Rhodolite	1	20 - 30	20 - 30
Ruby	1	2,450 - 3,900	2,450 - 3,900
Sapphire	1	800 - 1,800	800 - 1,800
Tanzanite	1	125 - 220	125 - 220

1/ Fine quality.
2/ Jewelers' Circular-Keystone. V. 167, No. 3, Jan. 1996, p. 142; and V. 168, No. 1, Jan. 1997, p. 290. These figures represent a sampling of net prices that wholesale colored stone dealers in various U.S. cities charged its cash customers during the month for fine-quality stones.

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TABLE 6
U.S. EXPORTS AND REEXPORTS OF DIAMOND (EXCLUSIVE OF INDUSTRIAL DIAMOND), BY COUNTRY 1/

Country	1995 Quantity (carats)	1995 Value 2/ (millions)	1996 Quantity (carats)	1996 Value 2/ (millions)
Belgium	658,000	$475	576,000	$547
Canada	123,000	44	135,000	50
France	23,900	31	24,000	43
Hong Kong	462,000	436	324,000	400
India	146,000	21	137,000	21
Israel	496,000	480	546,000	558
Japan	150,000	159	106,000	139
Russia	9,930	23	569	4
Singapore	26,500	57	18,100	55
Switzerland	54,100	183	50,500	234
Thailand	124,000	32	95,000	42
United Arab Emirates	10,500	5	6,320	7
United Kingdom	10,900	64	31,900	94
Other	35,800 r/	35 r/	40,900	32
Total	2,330,000	2,040	2,090,000	2,230

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY 1/

Kind, range, and country of origin	1995 Quantity (carat)	1995 Value 2/ (millions)	1996 Quantity (carat)	1996 Value 2/ (millions)
Rough or uncut, natural: 3/				
Australia	34,200	(4/)	74,600	$1
Belgium	181,000	$119	277,000	149
Brazil	4,910	1	38,500	5
Ghana	162,000	119	157,000	105
India	61,900	1	11,100	(4/)
Russia	34,900	33	34	(4/)
Israel	36,500	22	33,600	34
South Africa	17,800	26	21,900	33
Switzerland	6,950	10	20,900	44
United Kingdom	969,000	155	658,000	200
Venezuela	19,900	(4/)	11,300	2
Zaire	82,600	82	92,000	84
Other	100,000 r/	65 r/	51,500	75
Total	1,710,000	631	1,450,000	731
Cut but unset, not more than 0.5 carat:				
Belgium	677,000	181	841,000	232
Brazil	6,450	1	9,490	3
Canada	3,990	1	18,000	4
Hong Kong	216,000	39	358,000	68
India	7,240,000	1,190	7,140,000	1,250
Israel	769,000	352	890,000	387
Netherlands	--	--	1,000	(4/)
South Africa	8,580	4	5,350	7
Switzerland	8,600	1	7,420	2
Thailand	65,000	10	54,600	8
United Kingdom	8,260	2	1,450	1
Other	47,300 r/	13 r/	62,600	23
Total	9,050,000	1,790	9,390,000	1,980
Cut but unset, over 0.5 carat:				
Belgium	873,000	1,110	833,000	1,190
Hong Kong	43,600	64	48,300	60
India	326,000	196	259,000	151
Israel	1,490,000	1,740	1,580,000	2,020
Netherlands	300	1	199	1
Russia	40,500	63	39,400	53

See footnotes at end of table.

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TABLE 7--Continued
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY 1/

Kind, range, and country of origin	1995 Quantity (carat)	1995 Value 2/ (millions)	1996 Quantity (carat)	1996 Value 2/ (millions)
Cut but unset, over 0.5 carat--Continued:				
South Africa	15,100	37	15,800	52
Switzerland	19,600	196	16,100	163
United Kingdom	8,290	38	6,820	53
Other	64,800 r/	80 r/	69,400	111
Total	2,880,000	3,530	2,870,000	3,850

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Includes some natural advanced diamond.
4/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY 1/

Kind and country	1995 Quantity (carats)	1995 Value 2/ (millions)	1996 Quantity (carats)	1996 Value 2/ (millions)
Emerald:				
Belgium	27,000	$4	13,900	$2
Brazil	2,620,000	6	4,340,000	7
Canada	9,940	1	15,600	1
China	1,610	1	1,550	(3/)
Colombia	1,130,000	94	968,000	74
France	1,500	2	3,340	2
Germany	24,600	2	13,900	2
Hong Kong	315,000	17	304,000	17
India	2,570,000	47	3,280,000	39
Italy	10,300	(3/)	7,540	(3/)
Israel	116,000	27	401,000	26
Japan	1,300	(3/)	3,020	1
South Africa	474	(3/)	1,370	(3/)
Switzerland	50,900	26	89,800	18
Taiwan	3,890	(3/)	207	(3/)
Thailand	418,000	7	358,000	8
United Kingdom	2,630	1	2,330	3
Other	10,800 r/	2 r/	138,000	3
Total	7,320,000	236	9,930,000	203
Ruby:				
Belgium	14,600	1	11,000	1
Brazil	233	(3/)	11,300	(3/)
Canada	11,700	(3/)	9,540	(3/)
China	2,270	(3/)	9,020	(3/)
Colombia	438	(3/)	423	(3/)
France	482	2	1,260	1
Germany	129,000	1	31,000	1
Hong Kong	278,000	6	377,000	7
India	1,370,000	6	2,340,000	6
Israel	8,360	1	25,400	1
Italy	10,200	1	83	(3/)
Japan	1,050	(3/)	2,240	(3/)
Switzerland	52,400	18	14,900	17
Thailand	2,270,000	41	3,010,000	44
United Kingdom	13,900	2	3,370	4
Other	15,100 r/	3 r/	57,100	3
Total	4,180,000	84	5,910,000	86
Sapphire:				
Australia	49,900	1	9,190	(3/)
Austria	214	(3/)	56	(3/)
Belgium	9,280	(3/)	25,900	1
Brazil	7,570	(3/)	8,190	(3/)

See footnotes at end of table.

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TABLE 8--Continued
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY 1/

Kind and country	1995 Quantity (carats)	1995 Value 2/ (millions)	1996 Quantity (carats)	1996 Value 2/ (millions)
Sapphire--Continued:				
Canada	82,200	(3/)	4,840	(3/)
China	1,670	(3/)	506,000	1
Colombia	1,270	(3/)	395	(3/)
France	863	1	738	1
Germany	146,000	2	64,500	2
Hong Kong	505,000	4	298,000	6
India	329,000	1	682,000	2
Israel	17,500	2	67,800	3
Italy	4,400	(3/)	10,500	(3/)
Japan	831	(3/)	1,640	(3/)
Korea, Republic of	--	--	1,110	(3/)
Singapore	1,250	(3/)	84	1
Sri Lanka (ceylon)	328,000	9	864,000	10
Switzerland	17,700	13	23,100	10
Tanzania	4,060	(3/)	3,010	(3/)
Thailand	5,240,000	49	5,920,000	55
United Kingdom	7,750	2	8,030	3
Other	20,100 r/	1 r/	26,600	2
Total	6,780,000	84	8,530,000	95
Other:				
Rough, uncut:				
Australia	NA	$3	NA	$4
Brazil	NA	32	NA	21
Colombia	NA	3	NA	1
Fiji	NA	(3/)	NA	1
Hong Kong	NA	1	NA	1
India	NA	1	NA	1
Kenya	NA	1	NA	2
Nigeria	NA	(3/)	NA	(3/)
Pakistan	NA	1	NA	(3/)
Philippines	NA	1	NA	1
Russia	NA	9	NA	(3/)
South Africa	NA	(3/)	NA	(3/)
Switzerland	NA	(3/)	NA	(3/)
Tanzania	NA	1	NA	1
Thailand	NA	1	NA	1
United Kingdom	NA	(3/)	NA	1
Zambia	NA	1	NA	2
Other	NA	6 r/	NA	12
Total	NA	61	NA	50
Cut, set and unset:				
Australia	NA	6	NA	5
Brazil	NA	8	NA	8
Canada	NA	(3/)	NA	(3/)
China	NA	5	NA	5
French Polynesia	NA	7	NA	4
Germany	NA	14	NA	11
Hong Kong	NA	23	NA	24
India	NA	13	NA	18
Israel	NA	5	NA	5
Japan	NA	11	NA	20
Kenya	NA	1	NA	1
Sri Lanka (ceylon)	NA	3	NA	3
Switzerland	NA	1	NA	2
Taiwan	NA	2	NA	2
Tanzania	NA	2	NA	2
Thailand	NA	19	NA	25
United Kingdom	NA	1	NA	1
Other	NA	2 r/	NA	4
Total	NA	125	NA	138

r/ Revised. NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 9
VALUE OF U.S. IMPORTS OF SYNTHETIC AND IMITATION GEMSTONES, BY COUNTRY 1/

(Thousand dollars) 2/

Country	1995	1996
Synthetic, cut but unset:		
Australia	1,120	768
Austria	6,250	5,320
China	2,830	4,880
France	1,010	1,090
Germany	11,000	12,100
Hong Kong	1,390	2,060
India	938	1,000
Italy	1,120	318
Japan	512	93
Korea, Republic of	1,360	1,440
Sri Lanka (Ceylon)	510	649
Switzerland	4,430	3,780
Thailand	7,910 r/	6,410
Other	840 r/	855
Total	41,200	40,700
Imitation: 3/		
Austria	59,900	46,200
China	575	414
Czech Republic	12,800	17,300
Germany	1,640	2,360
Japan	503	788
Taiwan	448	214
Other	1,240	1,270
Total	77,100	68,500

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Includes pearls.

Source: Bureau of the Census.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES 1/

(Thousand carats and thousand dollars)

Stones	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Diamonds:				
Rough or uncut	1,710	631,000	1,450	731,000
Cut but unset	11,900	5,320,000	12,300	5,830,000
Emeralds: Cut but unset	7,320	236,000	9,930	203,000
Coral and similar materials, unworked	NA	4,020	NA	6,340
Rubies and sapphires: Cut but unset	11,000	168,000	14,400	181,000
Pearls:				
Natural	NA	3,260	NA	1,100
Cultured	NA	30,400	NA	31,800
Imitation	NA	1,660	NA	1,740
Other precious and semiprecious stones:				
Rough, uncut	1,420,000	48,600	1,610,000	37,400
Cut, set and unset	NA	91,500	NA	105,000
Other	NA	8,800	NA	6,320
Synthetic:				
Cut but unset	160,000	41,200	174,000	40,700
Other	NA	1,830	NA	3,800
Imitation gemstone 3/	NA	75,400	NA	66,800
Total	XX	6,660,000	XX	7,240,000

NA Not available. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Does not include pearls.

Source: Bureau of the Census.

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TABLE 11
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY 1/ 2/

(Thousand carats)

Country	1992	1993	1994	1995	1996
Gemstones: 3/					
Angola 4/	1,100	130	270	2,700 r/	3,600
Australia	18,100	18,800	19,500	18,300	18,897 5/
Botswana	11,200	10,300	10,550 5/	11,500	11,000
Brazil	653	1,000 r/	300 r/	700 r/	700
Central African Republic	307 5/	370	400	400	350
China	200	230	230	230	230
Gabon	400	400	400	400	400
Ghana	104 r/ 5/	106 r/ 5/	118 r/	126 r/	125
Nambia	1,520	1,120	1,312 5/	1,382 5/	1,300
Russia	9,000	8,000	8,500	9,000	9,250
Sierra Leone	180	90	155	113 5/	162
South Africa	4,600	4,600	5,050 r/	5,070 r/	5,360
Venezuela	302	145 r/ 5/	203	229 5/	230
Zaire	8,930	2,010	4,000	4,000	3,000
Other	305	277 r/	463 r/	608 r/	813
Total	56,800 r/	47,600 r/	51,400	54,800 r/	55,400
Industrial:					
Angola 4/	80	15	30	300 r/	400
Australia	22,100	23,000	23,800	22,400	23,096 5/
Botswana	4,790	4,420	5,000	5,300	5,000
Brazil	665	600 r/	600 r/	600 r/	600
Central African Republic	107 5/	125	131	130	120
China	800	850	850	900	900
Gabon	100	100	100	100	100
Ghana	590 r/ 5/	484 r/ 5/	473 r/ 5/	505 r/	505
Nambia	30	20	--	--	--
Russia	9,000	8,000	8,500	9,000	9,250
Sierra Leone	116	68	100	101 r/	108
South Africa	5,600	5,700	5,800 r/	5,880 r/	6,000
Venezuela	176	155 5/	214 5/	64 5/	60
Zaire	4,570	13,600	13,000	13,000	15,000
Other	218	210 r/	277 r/	344 r/	464
Total	48,900 r/	57,400	58,900 r/	58,600 r/	61,600
Grand total	106,000	105,000	110,000	113,000 r/	117,000

r/ Revised.
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through May 28, 1997.
3/ Includes near-gem and cheap-gem qualities.
4/ Figures do not include smuggled artisanal production.
5/ Reported figure.

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GERMANIUM

By Earle B. Amey

Germanium is a grayish-white, metallic element with the properties of a semiconductor, i.e., electrical characteristics between those of a metal and an insulator. It is commercially available as a tetrachloride, a high-purity oxide, and in the form of zone-refined metal ingots, single-crystal bars, castings, doped semiconductors, optical materials, optical blanks, and other specialty products. Germanium is extensively used to make elements for infrared optical devices. Its excellent mechanical, optical, and electrical properties, as well as its moderate cost and availability in large sizes make it attractive in many aerospace applications. The end use pattern for germanium in 1996 was estimated to be as follows: fiber-optic systems, 40%; polymerization catalysts, 20%; infrared optics, 15%; electrical/solar applications, 15%; other uses, 10%.

The domestic germanium industry consisted of two zinc mining operations in Alaska and Tennessee, which supplied byproduct germanium concentrates to the domestic and export markets, and three refineries, in New York, Oklahoma, and Pennsylvania. The refineries processed manufacturer's scrap, along with imported concentrates; very little old (postconsumer) scrap was available for recycling. Domestic refinery production, which amounted to about one-third of the world refinery production in 1996, was estimated to be worth $30 million to $40 million. Domestic refinery production and consumption for germanium are estimated by the U.S. Geological Survey (USGS) on the basis of discussions with domestic producers. Domestic refinery production of germanium was estimated to have increased significantly in 1996, while U.S. consumption was judged to have decreased slightly.

The USGS estimated domestic germanium reserves at 450,000 kilograms, equivalent to 18 years of domestic consumption at the 1996 rate; figures for worldwide reserves were not available. Worldwide, germanium resources are associated with zinc and lead-zinc-copper sulfide ores.

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984, with an initial goal of 30,000 kilograms of germanium metal. In 1987, a new NDS goal of 146,000 kilograms was established; this was later adjusted downward in 1991 to 68,198 kilograms. At yearend 1996, the actual inventory was 68,207 kilograms of germanium metal. The Defense Logistics Agency, which maintains the NDS, made plans to sell germanium at a rate of 4,000 kilograms per year through 2005. All of the material to be offered is zone refined polycrystalline germanium metal (U.S. Department of Defense, 1997).

Production

The USGS estimated domestic refinery production from both primary and secondary materials in 1996 to be 18,000 kilograms, much more than in any of the prior 3 years. In 1996, Eagle-Picher Industries Inc.'s Quapaw, OK, Electro-Optic Materials Department remained the largest producer in the United States, but is no longer recovering primary germanium from zinc smelter residues. Eagle-Picher produced germanium from reprocessed scrap, fly ash, and germanium concentrates.

Cabot Corp., Revere, PA, and Atomergic Chemetals Corp., Plainview, NY, produced germanium from reprocessed scrap and semirefined foreign material. The zinc refinery at Clarksville, TN, which Savage Resources Ltd. acquired in 1994, continued to produce germanium-rich residues as a byproduct of processing zinc ores from the associated Elmwood-Gordonsville Mine. The new operating company, Savage Zinc, Inc., continued the established practice of shipping these residues to Union Minière's Germanium Business Unit in Belgium for germanium recovery and refining.

Consumption

The USGS estimated domestic consumption of germanium in 1996 at approximately 25,000 kilograms, down somewhat from the 1995 level. The estimated world consumption pattern in 1996 was as follows: fiber optics, 40%; polymerization catalysts, 20%; infrared-optical systems, 15%; electrical/solar applications, 15%; and other applications (phosphors, metallurgy, and chemotherapy), 10%.

Fiber optics and infrared optical systems continued to be the principal industrial end uses for germanium in the United States. In the fiber optics sector, germanium was employed as a dopant within the core of many optical fibers used by the telecommunications industry. In addition, germanium-containing lenses and windows are transparent to infrared radiation, a property that has led to their use in infrared optical systems. These optics are employed principally for military guidance and weapon-sighting applications. Germanium glass was also used for nonmilitary surveillance and monitoring systems in fields such as satellite systems and fire alarms.

Prices

In 1996, domestic producer prices for germanium metal and dioxide increased over the long-standing price levels first established in late 1981 ($1,060 and $660 per kilogram, respectively). Throughout this 1981-96 period, significant

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discounting by producers was evident because of competition from imported materials. In 1996, producer prices for zone refined metal reportedly reached $2,000 per kilogram and germanium dioxide producer prices were at $1,300 per kilogram.

Free market prices for germanium dioxide, published by Metal Bulletin (London), started 1996 at $860 to $960 per kilogram and ended the year in the $1,200 to $1,280 per kilogram range. The price for Belgian-produced germanium dioxide, published by Metal Bulletin (London), started the year at about $850 per kilogram, rose to approximately $935 at the end of February, and maintained that level until the close of the year.

Prices continued to increase dramatically through the summer as the world production was not sufficient to meet growing demand, and promised sales from Russia, Ukraine, and the United States stockpile did not materialize. High prices have resulted in increased production of germanium by existing producers, the development of new sources of supply, and increased recycling (Roskill's Letter from Japan, 1996).

Foreign Trade

In 1996, the estimated germanium content of imports was approximately 27,500 kilograms, about 70% higher than in 1995. Russia, the United Kingdom, Belgium, China, and Germany, in descending order of shipments, accounted for approximately 96% of U.S. germanium imports for 1996. *(See table 1.)* Imports directly attributable to countries of the former Soviet Union amounted to 15,200 kilograms, about a 300% increase from the previous year's level. Increased shipments from Russia accounted for the sharp rise in imports.

World Review

World refinery production was estimated at 53,000 kilograms in 1996, an increase of about 18% from 1995 production levels. The sales from Ukrainian stockpiles totaled 6,500 kilograms, while 12,000 kilograms was recycled worldwide. Hence, 71,500 kilograms of germanium was available for consumption in 1996. The total world germanium refinery capacity was judged to have declined in 1996 and was estimated at approximately 150,000 kilograms.

Japan.—The Japanese market for PET (polyethylene terephthalate) containers continued to grow at about 3.1% per year (Roskill's Letter from Japan, 1996). This growth represents an equivalent increase in the consumption of germanium owing to its use as a catalyst in making PET.

Russia.—Stocks as high as 8,500 kilograms of germanium and 29,000 kilograms of germanium dioxide reportably were available for immediate disposal (Metal Bulletin, 1997b).

Spain.—Asturiana de Zinc produced 6,500 kilograms of germanium grading 66% at its Arnao powder plant from concentrates taken from the Reocin zinc and lead mine (Metal Bulletin, 1997a).

Ukraine.—Ukraine's Zaporozhya titanium-magnesium plant planned to sell 4.33 metric tons of germanium from government reserves to raise money for modernization. The time frame for the sale was unspecified, but the value of the material was estimated at $7 million (American Metal Market, 1996).

Current Research and Technology

A controversy exists on the toxicity of "organic germanium" found in certain dietary supplements. The proponents of "organic germanium" claim that it increases the flow of oxygen to the bloodstream, relieves pain, and strengthens the immune system. On the other hand, the Food and Drug Administration and the National Council Against Health Fraud have linked "organic germanium" to kidney failure and dispute that any health benefits can really be derived from the product (Pilat, William, Indiana School of Business, written commun., 1997). On October 10, 1989, the British government warned all doctors in England of health risks from germanium compounds widely sold in health-food stores. Persons with AIDS and chronic fatigue are especially likely to use germanium (James, 1989).

The task of accurately aligning and affixing fibers or lenses, commonly known as "pigtailing," to the photonic devices such as fiber optic cables or laser diodes remains one of the most difficult and expensive in the manufacturing process. Automation is finding wide acceptance as a solution for lowering costs and providing improved performance in high-volume applications. Recent increases in production have driven the need for complete "align-and-attach" automation solutions. In a recent demonstration at Lawrence Livermore National Laboratory, an automated fiber-pigtailing machine automatically loaded, aligned, and epoxy-bonded conveyor-loaded trays of multichannel waveguides without operator assistance (Photonics Spectra, 1997).

Outlook

In 1996, germanium supplies were sufficient on a worldwide basis to meet the demand for this specialty metal and its related products. The 1995 shortage of production and increased demand for virgin germanium that had led to a very tight world supply of germanium was moderated by increased production from North American sources, releases from various national stockpile holdings, and increased shipments from China. However, future germanium supplies could remain tight if the increased demand from the fiber optics sector continues as has been projected (Fiberoptic Product News, 1997) and new or expanded sources of supply are not brought on-line in the very near future. In fact, if the prevailing supply-demand situation remains in place, prices of processed germanium may be expected to continue at elevated levels. In this environment, competition from alternative materials will become an increasingly significant factor in germanium markets, especially if prices reach and maintain extremely high levels for extended periods of time.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
U.S. IMPORTS OF GERMANIUM, BY CLASS AND COUNTRY 1/

Class and country	1995 Gross weight (kilograms)	1995 Value	1996 Gross weight (kilograms)	1996 Value
Unwrought and waste and scrap:				
Austria	--	--	6	$6,170
Belgium	3,620	$3,870,000	3,960	6,700,000
Canada	--	--	1	4,430
China	2,420	1,470,000	2,860	4,490,000
Estonia	18	11,700	169	254,000
Finland	--	--	64	70,500
France	25	27,400	26	36,300
Germany	171	66,300	493	306,000
Hong Kong	97	102,000	50	45,800
Israel	182	126,000	106	229,000
Japan	232	135,000	96	180,000
Korea, Republic of	269	26,200	--	--
Latvia	--	--	96	95,600
Lithuania	185	29,700 r/	--	--
Netherlands	--	--	108	75,400
Romania	--	--	39	19,000
Russia	2,960	1,940,000	14,600	13,100,000
Ukraine	651	373,000	296	447,000
United Kingdom	5,380	2,120,000	4,550	4,720,000
Total	16,200	10,300,000	27,500	30,800,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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GOLD

By Earle B. Amey

Total world gold mine production increased slightly and was well within 1% of the all-time high reached in 1993. Despite a third successive decline in production, South Africa remained the world's largest of more than 80 gold-producing nations, followed by the United States, Australia, Canada, and China. The United States has been the second largest producer since 1991 when its production surpassed that of the former Soviet Union, for the first time in nearly five decades. Nevada produced two-thirds of domestic production; the other one-third came from 12 other States. Although most domestic gold mines were open-pit mines, interest in underground methods continued to increase as more near-surface deposits reached depletion. Some of the deeper deposits, accessible only by underground methods, contain higher grade sulfide ores that require more extensive processing than the oxidized ores encountered in most near-surface operations. Along with this shift in ore types and the related maturing of the U.S. gold mining industry, there has also been a trend toward a smaller total number of operating gold mines but with an associated shift to larger capacity mining operations; that is, fewer but larger gold mines. Although the majority of the Nation's gold mines were in the Western States, several were in operation in two States, South Carolina and Wisconsin, east of the Mississippi River. Gold was also produced at about 120 lode mines (of which about 75 were major), a dozen or more large placer mines, nearly all in Alaska, and numerous small placer mines, mostly in Alaska and the Western States. A minor amount of domestic gold also was produced as a byproduct of processing the ores of base metals, principally copper. Of the gold produced in the United States, 23 mines yielded 83%. The value of U.S. gold mine production was about $4 billion.

Domestic gold exploration activity, which peaked during the late 1980's, continued a trend of expanding on a total dollar basis while shrinking on a percentage basis as mining companies pursued opportunities overseas (D. Wilburn, Materials and Minerals Specialists, U.S. Geological Survey, written commun., Mar. 3, 1997). Many countries have revised their mining laws, offering incentives for foreign investment, and in some cases, have opened up areas previously not available for exploration. This focus on overseas exploration and development targets by U.S. companies was directed toward various areas in the southwestern Pacific, Western Africa, and the newly independent republics of the former Soviet Union.

Approximately two dozen domestic producers produced commercial-grade refined gold. Of several thousand companies and artisans, a few dozen companies dominated the fabrication of gold into marketable products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas; other areas of concentration were in California, Florida, and Texas.

According to the World Gold Council, 1996 marked the fifth consecutive year of sales increases for gold jewelry in the United States. Total U.S. gold jewelry sales reached $12.3 billion, up 5% from sales in 1995. Dollar and unit sales reportedly had increased through 21 consecutive quarters (World Gold Council, 1996).

Trade in refined bullion comprised 90% of U.S. gold imports and 86% of exports; net exports of bullion rose to 263,000 tons, up about 60% from that of 1995. Canada provided more than one-half of the bullion imported, and Switzerland was the destination for nearly one-half of the bullion exported. Most imports of unwrought gold, including bullion and doré, enter the U.S. duty free.

The dollar price for gold remained listless throughout the year. The Engelhard Industries' daily price of gold ranged from a low of about $369 per troy ounce[1] on December 3 to a high of nearly $391 on August 5. The average for the year was, to the nearest dollar, $389. The previous year's prices ranged from about $373 to $397 and averaged $386.

In June, gold leasing rates reached their lowest level for 1996, suggesting, in the absence of significant additional supply of liquidity to the market, low levels of demand for borrowed gold (Murray and others, 1997, p. 31).

Identified world gold resources at yearend 1996 were estimated at 86,000 tons, of which 15% to 20% was byproduct resource; the world reserve base was estimated (R. Ashley, Gold Resource Specialist, U. S. Geological Survey oral commun., Oct. 6, 1996) to be 71,000 tons and reserves at 46,000 tons. South Africa had about one-half of the resources and reserve base and 41% of the reserves. The United States had about 10% of world resources, 8% of the reserve base, and 12% of the reserves.

Of an estimated 121,000 tons of gold mined in historical times through 1996 (Thomas and Boyle, 1986), about 15% is thought to have been lost, used in dissipative industrial uses, or otherwise unaccounted for or unrecoverable. Of the remaining 103,000 tons, about 35,000 tons is official stocks held by central banks and about 68,000 tons is privately held as bullion, coin, and jewelry.

Production

Domestic mine production data for gold were derived by the USGS from two separate voluntary surveys of U.S. operations. One of these surveys is the production survey of copper, gold,

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lead, silver, and zinc lode mines. Of the lode gold producers in operation to which a survey request was sent, 115 responded, representing 97% of the total gold shown in tables 1 and 2. The individual company production and performance data cited in this report were obtained from published sources, such as company annual reports.

Of the total gold produced during 1996, 91% was extracted from gold ore, and the remainder was derived from base-metal ores, other precious-metal ores, and placer deposits. By comparison, similar data assembled for 1980 indicated that gold ores provided 63% of the total gold produced and the remainder, 37%, was derived from base-metal ores, other precious-metal ores, and placers. In both years, the contribution from placer mines amounted to less than 2% of the total gold produced.

Alaska.—The State's Division of Geology and Geophysical Surveys reported that gold output increased slightly from an estimated 4.4 tons (142,000 ounces) worth $56.0 million in 1995 to 4.5 tons (145,000 ounces) worth $56.4 million in 1996, or an approximate increase in production of 2% and a increase in associated value of 1% (Swainbank and others, 1997). An estimated 144 placer mines were operating in 1996, about the same as in 1995. A big drop in placer production, from 4,220 to 3,090 kilograms of gold, was due to the permanent closure of Cambior Alaska Inc.'s Valdez Creek Mine, the State's largest gold mine for 12 years, in September 1995. The new underground Nixon Fork copper-gold mine near McGrath that began to produce gold during the fourth quarter of 1995 became Alaska's largest gold mine in 1996. Nixon Fork Mining Co., the operating subsidiary for Consolidated Nevada Goldfields Co., reported that the project mined and milled about 1,200 kilograms of gold (Consolidated Nevada Goldfields Corp., 1996).

USMX, Inc. (1996e), Lakewood, CO, announced that significant progress had been made toward the completion of a feasibility study to evaluate the economics of its Illinois Creek gold and silver property in west-central Alaska. USMX reported that results to that point had been positive and, on a preliminary basis, indicated that the property contained about 4.5 million tons of drill-defined mineralization at a grade of 2.5 grams (0.074 ounce per short ton) of gold per ton, amounting to about 10,900 kilograms of contained gold. The company plans to mine the property over a 5-year period and heap–leach run-of-mine ore to recover more than 1,560 kilograms of gold per year. By early June, USMX, Inc. (1996a), Lakewood, CO had received the key permits from the State of Alaska necessary to begin construction at Illinois Creek; the package of approved permits included all permits necessary to begin development of gold mining and leaching facilities at the site. However, on November 14th , USMX, Inc. (1996c), Lakewood , CO, announced that it had decided to defer commencement of gold production until the spring of 1997.

USMX, Inc. (1996d), Lakewood , CO, announced that it had received an exclusive exploration permit covering 5,420 hectares (13,380 acres) in the Ophir mining district in west-central Alaska.

Hecla Mining Co. (1996), Coeur d'Alene, ID, announced on July 29 that operations at the Greens Creek Mine on Admiralty Island, off Juneau, AK, had been restarted ahead of schedule. Grinding and flotation circuits at the silver/zinc/lead/gold mine were started the week of July 22, well ahead of the original schedule, which had called for the mine to restart operations in the first quarter of 1997. Greens Creek is a joint venture between Kennecott Greens Creek Mining Co. (70.3%) and Hecla (29.7%).

California.—Gold production in California reportedly dropped about 7% drop from that of 1995 as shown in table 2. This was apparently due, in part, to the June 1996 closure of Homestake Mining Co.'s McLaughlin Mine in Napa County and MK Gold Co.'s and Hecla Mining Co.'s American Girl Mine in Imperial County. Before the closures, the McLaughlin Mine, which had been California's largest gold mine, produced 5.8 tons (186,000 ounces) of gold from processed oxide and sulfide ore mined by open pit methods, and the American Girl Mine produced 1.4 tons (45,000 ounces) of gold. With the shutdown of the McLaughlin Mine, Santa Fe Pacific Gold Corp.'s Mesquite Mine near Brawley became California's largest gold mine, processing oxide and sulfide ore mined by open pit methods, recovering more than 5.8 tons (187,000 ounces) of gold from both surface and underground mines. In eastern Imperial County, Glamis Gold Ltd. continued to produce gold by using heap-leaching methods at its Picacho Mine and continued exploration at its nearby Imperial Project. The Picacho Mine produced a record 1.1 tons (34,600 ounces) during 1996 and is expected to produce more than of 0.9 ton (28,000 ounces) in 1997, at which time all known reserves on the property will have been depleted. Glamis, through its wholly owned Rand Mining Co., also produced 2.7 tons of gold (86,000 ounces) at its Rand Mine near Randsburg. Almost all mining has been carried out at the Yellow Aster Pit of the Rand Mine. Another major mine producing gold in Kern Counties during the year was the Cactus Mine.

In eastern San Bernardino County near the Nevada-California State line, about 95 kilometers southwest of Las Vegas, NV, the Castle Mountain Mine of Viceroy Resource Corp. and MK Gold produced an estimated 4.6 tons (147,000 ounces) of gold.

Siskon Gold Corp. reported (diGesu and others, 1997) that construction and development of its new San Juan Mine, north of Grass Valley was completed in mid-May 1996. Blasted gold-bearing gravels were transported by means of mechanized ladders from this new underground placer mine to an underground processing plant that produced gold concentrate. In the first 9 months of 1996, 0.3 ton (9,200 ounces) of gold was recovered from the raw concentrate by gravity concentration methods at the new surface-level processing plant.

Colorado.—The more than 60% increase in gold production was due , in no small part, to a full year of production from Pikes Peak Mining Co.'s Cresson Mine in the Cripple Creek District of Teller County. Golden Cycle Gold Corp. (1997) reported that this new open pit mining operation produced 5.4 tons (175,000 ounces) of gold in 1996. The closure of Battle Mountain Gold Co.'s San Luis Mine in Costilla County in late

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1996 will, however, result in a decline of gold production in 1997. Battle Mountain (1997) reported that the mine produced about 1.7 tons (54,000 ounces) of gold in 1996. Most of the site reclamation is expected to be completed during 1997.

Sunnyside Gold Corp., a subsidiary of Echo Bay Mines, Englewood, CO, filed a final consent decree in Denver's District Court to resolve its 1994 lawsuit against the State of Colorado's Department of Public Health and Environment. The dispute focused on the company's plan for complete closure of the Sunnyside polymetallic gold/silver mine near Silverton, CO. According to the agreement, the water quality in the Upper Animas River Basin in southwest Colorado will be maintained and improved by the removal of historic waste/tailings from abandoned mine sites outside the Sunnyside property, as well as, remediating long-abandoned mine sites that are the source of leached metals (Engineering & Mining Journal, 1996a).

Idaho.—With a full year production of 3.4 tons (109,000 ounces) from Meridan Gold Co.'s Beartrack Mine, near Salmon, the total gold production for Idaho rose about 27%.

Dakota Mining Corp.'s wholly owned Stibnite Mine in Valley County decreased its gold production from 1.5 tons (49,000 ounces) in 1995 to 0.9 ton (29,000 ounces) in 1996. Dakota Mining Corp. and Hecla Mining Co. announced plans to combine their gold mining interests in the Stibnite/Yellow Pine areas of Valley County. By this action, the companies plan to streamline the future development of the sulfide gold ore resources in the region, sharing these assets equally. Under the agreement, Dakota Mining will continue to mine its wholly-owned oxide gold reserves at the Stibnite site (Engineering & Mining Journal, 1996b).

Pegasus Gold Inc.'s Black Pine Mine in Cassia County also produced less gold; 2.7 tons (88,000 ounces) in 1996 versus 3.4 tons (109,000 ounces) in 1995. Black Pine reportedly (diGesu and others, 1997) will be mined out by mid-1997; residual production is scheduled to continue through 1997.

Gold production at the Grouse Creek gold mine near Challis declined about 8% from 2.6 tons (84,000 ounces) in 1995 to 2.4 tons (77,000 ounces) in 1996.

Montana.—According to the annual review of mining and mineral developments, prepared by the Montana Bureau of Mines and Geology, exploration budgets have been reduced to lobby against an initiative campaign, I-122, that addressees new-water quality standards (McCulloch, 1997).

Gold output slipped from 12.4 tons (400,000 ounces) in 1995 to 9.1 tons (293,000 ounces) in 1996 owing to the closure of TVX Gold Inc.'s Mineral Hill Mine in early September 1996 and the decline in residual production from the Kendall and the Zortman Mines (McCulloch, 1997).

Of the mines producing gold in Montana during the year, three were owned and operated by Pegasus Gold Inc.— the Beal Mountain Mine in Silver Bow County; the Montana Tunnels Mine, a gold, lead, silver, and zinc mine in Jefferson County that was the State's second largest gold mine in 1996; and the Zortman Mine in Phillips County. Their total gold production during the year amounted to about 5.1 tons (160,000 ounces).

Placer Dome (U.S.) Inc.'s wholly owned Golden Sunlight Mine near Whitehall is Montana's largest gold-producing mine with 3.7 tons (117,900 ounces) in 1996; production in 1995 had amounted to nearly 2.8 tons (89,800 ounces) of gold. The company indicated that it is working with the Montana Department of Environmental Quality to complete an Environmental Impact Statement for an expanded Stage 5 pit that will extend the main pit life by 3 years.

TVX Gold Inc. suspended production at its underground Mineral Hill Mine near Jardine and exploration work at its nearby Crevice Mountain Project. The facilities were placed under care and maintenance owing to continuing losses as a result of decreased ore grades. The Mineral Hill Mine reportedly (TVX Gold Inc., 1997) produced nearly 0.5 ton (17,300 ounces) of gold in 1996 compared with 1.1 tons (34,900 ounces) of gold in 1995.

Near Cooke City, the New World project was on hold as Federal officials and environmental groups negotiated the exchange of private landholdings and unpatented mineral rights currently owned by Crown Butte Mines Inc. for Federal property totaling $64 million (McCulloch, 1997). Federal plans for the gold, silver, and copper project call for underground mining and ore processing without the use of controversial heap-leaching or cyanide recovery methods.

Nevada.—Nevada maintained in its longstanding position as the Nation's dominant gold-producing State. Of the Nation's top 23 gold-producing mines, 13 were in the Silver State. Primary gold production increased slightly to 213 tons (6.8 million ounces) and is expected to rise to almost 220 tons (7 million ounces) in 1997 with several new mines on the horizon.

Barrick Gold Corp. was once again the Nation's largest gold mining company and reportedly recovered 60.2 tons (1.93 million ounces) of gold at its Betze-Post Mine in Eureka County. Nearby in Elko County, Barrick continued development of its Meikle Mine, a new underground operation that produced 2.4 tons (78,400 ounces) of gold. These Barrick operations on the Carlin Trend are developed within a 2,800-hectare landholding known as the Goldstrike property. In addition, Barrick's wholly owned Bullfrog Mine near Beatty produced nearly 6.4 tons (205,300 ounces) of gold.

In 1996, Newmont Gold Co. produced 52.9 tons (1.7 million ounces) of gold from its operations centered in Eureka and Elko Counties. It was the seventh consecutive year that Newmont had produced 1.5 million ounces (46.7 tons) or more from the Carlin Trend in northeastern Nevada. In May, Newmont marked 31 years of production on the Carlin Trend, which it discovered in the mid-1960's, with the pouring of its 551st ton (18 millionth ounce of gold). The company's extensive operations along the Carlin Trend include 11 open pit mines from which nearly 242 million tons of ore and waste was mined during the year, accounting for the bulk of Newmont's Carlin Trend production. The Gold Quarry Mine generated 54% of Newmont's Carlin area production, down from 67% in 1995. Mining reportedly (Newmont Gold Co., 1997) began at four new open pit mines in 1996–Bootstrap, Beast, Lantern, and Sold. Full-scale operations were achieved at Deep Star, the company's highest grade underground mine. In addition, gold

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from three other underground mines nearly tripled from an output of just 3.8 tons (123,000 ounces) in 1995 to 9.5 tons (307,000 ounces) of gold in 1996. To recover gold from the widely varying grades and many types of ore it is currently mining along the Carlin Trend, Newmont uses several processing methods. The company's $350 million refractory (sulfidic and carbonaceous) ore treatment plant, or roaster, which is reported to be the largest facility of its kind in the world, produced almost one-third of the company's Nevada production—16.8 tons (540,000 ounces) of gold during the year, an increase of 11.0 tons (354,000 ounces) from in 1995. All refractory ore from Newmont's underground operations was processed by the new roaster, which was originally designed to process 8,000 tons of ore per day but has consistently operated above that level, and at times, has produced more than 10,000 tons per day.

Northwest of Elko, Independence Mining Co. and FMC Gold Co. produced about 9.6 tons (309,000 ounces) of gold at their Jerritt Canyon Mine. Santa Fe Pacific Gold Corp. recovered 14.3 tons (459,000 ounces) of gold at its Twin Creeks Mine in Humboldt County, and about 6.4 tons (206,000 ounces) at its Lone Tree Mine to the south near Valmy. Both operations are open pit mines where gold was recovered by milling and heap-leaching methods. At the nearby Getchell Mine, FirstMiss Gold Inc. produced 5.5 tons (178,000 ounces) of gold from its underground operations. Other gold mines in Humboldt County include the Hycroft (formerly the Crofoot/Lewis), the Marigold , the Pinson, and the Sleeper Mines; although mining ended at the Sleeper Mine in the third quarter, residual leaching continued.

South of and parallel to the Carlin Trend, the Battle Mountain/Eureka Trend runs from southeastern Humboldt County southeast through Eureka. Gold mining operations along this trend include the Battle Mountain Complex of Battle Mountain Gold Co. in Lander County: the McCoy and Cove gold and silver property of Echo Bay Mines Ltd., the Cortez Gold Mine Joint Venture's Cortez Mine, and Alta Gold Co.'s Easy Junior Mine in White Pine County. Gold production is winding down at Easy Junior.

At Round Mountain, about 95 kilometers north of Tonopah, the Smokey Valley Common Operation at the Round Mountain Mine produced about 12.8 tons (411,000 ounces) of gold during the year.

Considerable exploration activity continued to be focused on Mineral Ridge, the Pipeline, Ruby Hill, and several other recent discoveries along the Battle Mountain/Eureka Trend in Lander and Eureka Counties.

South Dakota.—Gold production remained largely unchanged. Homestake Mining Co.'s 120-year-old Homestake Mine at Lead was again the Nation's largest underground gold mine, the largest gold-producing mine in South Dakota, and the sixth largest gold-producing mine in the country. During the year, the mine, a nearly 2.5-kilometer-deep operation with associated surface mining, yielded about 12.7 tons (407,000 ounces) of gold at a reported cash production cost of $293 per ounce.

Wharf Resources Ltd. continued to operate two open pit gold mines near Lead (the wholly-owned Wharf Mine and the 60%-owned Golden Reward Mine) in 1996. The Wharf Mine produced about 3.2 tons (105,000 ounces) of gold, and the Golden Reward Mine, about 0.7 ton (21,000 ounces). In September, the Golden Reward Mine was placed on care and maintenance following depletion of permitted reserves. Developing the unpermitted reserves of 3.9 tons at a grade of 0.035 ounces of gold per ton of ore would disrupt the surface of a local cemetery and could affect the operation of a nearby ski hill. As of yearend, a solution to the permitting had yet to be resolved.

In January, Dakota Mining Corp. successfully completed permitting work at its Anchor Hill oxide deposit on the Gilt Edge property, near Deadwood (Platt's Metals Week, 1996); this deposit is an oxidized sulfide deposit. Unlike unoxidized sulfide deposits, gold can be extracted from sulfide material in the oxide deposit through the use of cyanide heap-leaching solutions. More than 0.8 ton (26,000 ounces) of gold was recovered from sulfide material.

Utah.—Kennecott-Utah Copper Corp.'s Bingham Canyon Mine produced gold as a byproduct of its copper mining operations near Salt Lake City. Long ranked as one of the Nation's principal gold-producing mines, Bingham Canyon was the third largest gold producer in 1996. Kennecott also operated the nearby Barney's Canyon Mine, an open pit and heap-leaching operation.

Barrick Gold Corp.'s open pit Mercur Mine in Tooele County, Utah's largest primary gold producer, recovered about 2.6 tons (83,000 ounces) of gold. Mercur is expected to began closure activities in early 1997. Mill processing of tailings from earlier mining operations is expected to continue into late 1998, when the mill will close.

USMX Inc. (1996b) reported that reclamation at its Goldstrike Mine in Washington County was going smoothly; actual mining had been terminated in late 1994. A pilot bioreactor was constructed to treat heap effluent and to produce a "clean" discharge. Closure was set for 1997.

World Review

After 2 consecutive years of decline, world gold mine production rose slightly in 1996. Increasing production from mines in North America , South America and Australia has been enough to help offset a continuing sharp decline in gold output from South Africa. According to its annual review of world gold supply and demand, Gold Fields Mineral Services Ltd. calculated that the total global supply of gold in 1996 was 3,490 tons (112 million ounces) compared with the previous year's total supply of 3,330 tons (107 million ounces) in 1995 (Murray and others, 1997, p. 5). The two principal components of gold supply, mine production and old gold scrap, recorded only minor changes in 1996. Beyond these areas of slight change, however, were several significant developments within individual components of the supply-demand balance for the year. The most consequential of these developments was the

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first appearance of producer forward sales on the demand side as a result of a net year-on-year decline in forward selling. Other significant changes were a decline in investment interest and a switch to substantial disinvestments.

On the supply side, Gold Fields reported that a series of official transactions and statements ensured that any positive sentiment in the global gold market would be short-lived. First, in March, the Central Bank of Belgium sold part of their gold stocks, which historically had backed up their paper currency (Murray and others, 1997, p. 5). This was followed by protracted discussions within the International Monetary Fund about the possibility of selling 5% of its gold reserves to aid some of the most heavily indebted countries. Next came the announcement by the Swiss National Bank of a radical change in its previously passive policy on gold (Murray and others , 1997, p. 6) . Finally, the Dutch Central Bank announced in a fourth quarter sale of 300 tons of gold from its reserves (World Gold Council, 1997).

On the demand side, Gold Fields reported that the total amount of gold used in the fabrication of marketable products rose by 1% to a record 3,290 tons (106 million ounces) (Murray and others, 1997, p. 5). Demand reportedly increased modestly in most fabrication markets; the main increases came from jewelry. The total worldwide demand for gold used in the fabrication of jewelry products rose by 1.4%, to 2,800 tons (90 million ounces). Demand in the second largest fabrication market, other industrial applications, rose 1.5%, to 213 tons (about 7 million ounces). Worldwide fabrication in the industrial countries had shown virtually no growth since 1990. Over the same period, however, led by the jewelry sector, fabrication in developing countries increased by 40%, and the use of gold in other demand sectors, such as dentistry and electronic products, also reported gains. Medals and imitation coins did not (Murray and others, 1997, p. 45).

With regard to gold exploration, the Metals Economics Group of Halifax, Canada, determined from its annual survey of worldwide exploration budgets for 223 companies that the percentage of overall exploration expenditures directed to gold targets rose to 60.9% in 1996, the highest level devoted to gold since 1989 (Beamish and others, 1996).

Australia.—Australian gold mine production increased by 14% in 1996, to reach its highest level ever, helping Australia retain its position as the world's third largest gold-producing nation. Of the 289 tons (9.3 million ounces) of gold mined in 1996, Western Australia, Queensland, and the Northern Territory accounted for about 76%, 10%, and 6%, respectively; Western Australia's production was derived principally from mining operations near Kalgoorlie. Other Australian gold-producing States were in descending order of output, New South Wales, Victoria, Tasmania, and South Australia.

A number of gold mines were under development or expanding capacity, and several new mines, such as Henry, Brocks Creek, and White Devil began production. In addition, 15 tons of gold were added to the national output by the Jundee, the Nimary, and the Tanami Mines, which had started up in 1995 but had their first full year of production in 1996.

Exploration for gold deposits continued with renewed vigor. Much of the exploration was directed at deeper lying deposits. This vigor further confirmed the opinion that the Native Title Act of 1993 had not and would not force the mining industry to abandon. There was, however, a further cause for ongoing concern with the matter of the native title. The Supreme Court's December ruling in the Wik decision that native title could coexist with pastoral leases, which account for about 40% of the land in Australia, created great uncertainty regarding hierarchy of title and security of tenure of holders of mining leases (Murray and others, 1997, p. 24).

Canada.—In 1996, gold production continued to rebound, reversing the downward trend from 1992 through 1994. New mines and expansions should result in a continuation of increased gold production until the end of the decade, according to a review of Canadian gold developments (G. Couturier, Natural Resources Canada, 1997, written commun./unpub. data). Canada retained its position as the world's fourth largest gold producer. Gold was produced at about 50 lode gold mines, accounting for 89.5% of the total gold output. Base metal mines and placer mines accounted for 8.4% and 2.1%, respectively, of the remainder. During the year, five gold mines began operation and three mines shut down. Canada's principal gold-producing regions were, in descending order of output, Ontario, Quebec, British Columbia, and the Northwest Territories. Gold was also produced in Alberta, Manitoba, New Brunswick, Newfoundland, Saskatchewan, and Yukon Territory.

Latin America.—Gold production in this part of the world rose by 7%, to about 277 tons (8.90 million ounces). For the third year in a row, Latin America spent the most on exploration ($963 million in 1996) primarily because of continued mining law and tax reforms and favorable geology. The most active exploration activities were focused in Chile and Peru (D.R. Wilburn, U.S. Geological Survey, written commun., 1996).

For the first time since the 1960's, production in Peru exceeded that in Brazil, making it the largest gold producer in Latin America at just under 65 tons (2.1 million ounces) of gold. The growth of the Peruvian mining industry has been quite phenomenal, with gold production increasing 500% in the last 10 years. Much of this success is attributable to Newmont Gold Co.'s and Cia. de Minas Buenaventura's low-cost heap-leach Yanacocha Mine in northern Peru, which produced more than 25 tons (800,000 million ounces) of gold. Yanacocha's continued expansion, has made it the largest gold mining operation in Latin America for the second consecutive year. The production from Peru's informal sector, which includes the gold-producing areas of Madre de Dios and Juliaca-Puno, however, remained about the same as that of 1995.

During 1996, Brazil produced about the same amount of gold, 62.5 tons (2.0 million ounces), as it did last year. The formal mining sector stabilized at about 41 tons (1.3 million ounces) of gold. The mines of the State-owned Cia. Vale do Rio Doce (CVRD), still Brazil's largest gold producer, yielded 18.0 tons (579,000 ounces) of gold. CVRD opened two new mines, Almas (Tocantins State) and Caeté (Minas Gerais State) and ceased operations at two other mines. Presently, the Igarapé

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Bahia Mine, in the Carajás Mineral District, State of Pará, is the company's largest gold mine, with an annual production rate of more than 10 tons (322,000 ounces) of gold. Output from the informal mining sector drastically fell (almost 60%) because of depletion of accessible near-surface reserves, lower local prices, and increasing environmental control (Murray and others, 1997, p. 25).

Gold production in Chile registered the third consecutive annual increase, rising 1% to 40 tons (1.3 million ounces). Most of this gold was generated by Amax Gold Inc.'s and Bema Gold's Refugio Mine in Maricunga, Dayton Mining's Andacollo gold mine, the gold-silver Fachinal mining operation managed by Coeur d'Alene Mines Corp., the Pimenton gold mine, and the Escondida copper mine (Murray and others, 1997, p. 25).

Gold production in Mexico rose to more than 24 tons (775,000 ounces) in 1996 compared with 20 tons (643,000 ounces) in 1995. During the year, production began at Newmex's Lluvia de Oro Mine and Eldorado Corp.'s La Trinidad Mine. The country's mining sector has been revitalized by the introduction of new legislation that encourages investment and exploration (Murray and others, 1997, p. 26).

Total gold output recovered in Guyana following the temporary closure of Cambior's Omai gold mine in August 1995; a tailings pond wall had failed, which had resulted in the release of several million cubic meters of cyanide-bearing effluent into the nearby Omai and Essequibo Rivers. The mine remained closed throughout the entire second half of 1995, then reopened in February 1996 and produced about 8 tons (255,000 ounces) of gold.

Oceania.—Gold production in Papua New Guinea declined for the fourth consecutive year, although at a slower rate than that of 1995. Output at Placer Pacific Ltd.'s Porgera Mine recovered after 3 years of decline, and reserves were significantly expanded during 1996, but this increase was not sufficient to offset falling output at Placer Pacific Ltd.'s Misima Mine. At the Ok Tedi Mine, the legal battle over compensation claims flowing from a spillage accident in 1994 was finally settled during 1996, but production had not returned to former levels. Nonetheless, the country's gold industry was beginning to recover, as shown by renewed interest in projects at Wau and in Hidden Valley; in the Porgera Mine, in which Placer Dome secured a much larger interest in the mine; and in the Lihir Gold Ltd.'s successful effort to raise capital (Murray and others, 1997, p. 27).

In Indonesia, gold output was estimated to have risen by 3.5% in 1996 and to have nearly quadrupled since 1991. Freeport Indonesia Inc. recovered slightly more than 52 tons (1.67 million ounces) of byproduct gold at its Grasberg/Ertsberg copper-gold mine in West Irian, and PT Kelian Equatorial Mining significantly increased its production of gold at the Kelian Mine in East Kalimantan. Gold exploration activities continued to increase, especially in Kalimantan, where Canada's Bre-X Minerals Ltd. of Calgary reported a major discovery at its Busang Project, which, it claimed, could possibly host several hundred metric tons of gold. Analysis of seven core holes drilled within the Busang Project area in an attempt to confirm these results, however, indicated insignificant amounts of gold. Additional analyses by an independent mining consultant gave further indication that Busang was unlikely to be proven an economic gold deposit (Wall Street Journal, 1997).

Gold output in New Zealand rose as a result of production increases from the Martha Hill and the Macraes gold mines.

Fiji now boasts two operating gold mines— Pacific Island Gold's Mount Kasi Mine, which began gold production on the island of Viti Levu in 1995, and the Emperor gold mine located at Vatukoula (Murray and others, 1997, p. 28).

Russia and the former Soviet Union.—Of the independent gold-producing countries resulting from the dissolution of the U.S.S.R. in late 1991, Russia is by far the largest producer in terms of output and number of operations, as well as areal distribution. The majority of Russia's production derives from formerly State-owned enterprises and worker's cooperatives, known as artels, which principally exploit placer deposits scattered throughout Siberia and the Russian Far East.

Production in Russia fell 9% to 120 tons (3.8 million ounces) of gold. This decline reflects the continued financial crisis prevailing in the country, which affected 28 of the 30 gold-producing regions; in Krasnoyarsk and the Altai territory output improved marginally. In contrast to the poor performance in Russia, production in Uzbekistan increased by almost 3%. This modest increase was largely as a result of Newmont Gold Co.'s efforts at Zarafshan, where about 218 million tons of low-grade stockpiled material had accumulated over 27 years of mining at the Muruntau Mine, the largest open-pit gold mine in the world (Murray and others, 1997, p. 25).

South Africa.— In 1970, the continent of Africa was the source of 81.8% of the world's gold output, but with the increase in production in North America and Australia, Africa's share had declined to only 26.6% in 1996. Gold production in South Africa, the world's largest gold-producing nation, declined for the third consecutive year to 498 tons (18.6 million ounces) of gold, more than 5% lower than that of 1995. Problems related to repeated labor disruptions, escalating costs, and declining ore grades continued to plague South Africa's gold-mining industry and combined to drive gold output down, bringing the cumulative decline in production from South African mines since 1993 to more than 20%.

The tonnage and grade of ore milled during 1996 by the nearly three dozen mines composing the membership of the Chamber of Mines of South Africa amounted to nearly 94 million tons at a grade of 4.91 grams per ton of gold; this compares with a similar total tonnage of 99 million tons, which was at the lower grade of 4.87 grams per ton, milled by Chamber members in 1995.

Of the top 15 gold-producing companies in the world in 1996, 6 were South African. Anglo American Corp. of South Africa Ltd. (AAC) remained the leading gold-producing company in the world. AAC owns the Freegold and the Vaal Reefs Mines. Gold Fields of South Africa Ltd. (GFSA) dropped from second in the world to third. GFSA owns the Driefontein and Kloof Mines. The other four companies were Gencor Ltd.

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(8th); Randgold and Exploration Co. Ltd. (10th); Johannesburg Consolidated Investment Co. Ltd. (11th); and Anglovaal Ltd. (13th) (Murray and others, 1997, p. 18).

Outlook

Gold remains an internationally traded metal, but unlike most commodities bound by the traditional laws of market supply and demand, it also serves as a trusted repository of wealth, a storehouse of value, held by investors and Governments alike. In recent years, average annual gold prices have remained in a rather tight range, but for the short term, the price is expected to drop. The main reason for the decrease is the threat of central bank gold sales. The Dutch government was a key catalyst last year, selling one-third of its reserves (300 tons of gold). Although the sales of reserve gold are not expected to be excessive, central banks continuing to be net sellers of gold bullion could set a limit to any price rallies that may develop over the next year.

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[1]Where used by itself elsewhere in this report, ounce refers to troy ounce; 1 kilogram of gold is equivalent to 32.1507 troy ounces.

[2]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT GOLD STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Mine production	kilograms	330,000	331,000	327,000	317,000 r/	321,000
Value	thousands	$3,660,000	$3,840,000	$4,050,000	$3,950,000 r/	$4,027,000
Gold recovered by cyanidation:						
Extracted in vats, tanks, and closed containers 2/	kilograms	178,000	177,000	169,000	155,000	158,000
Leached in open heaps or dumps 3/	do.	120,000	128,000	119,000	124,000	131,000
Refinery production:						
Ores, concentrates and dore	do.	284,000	243,000	241,000 4/	(4/)	(4/)
Recycled materials (new and old scrap)	do.	163,000	152,000	148,000 4/	(4/)	(4/)
Imports for consumption:						
Refined	do.	141,000	130,000	96,400	111,000	143,000
Exports:						
Refined	do.	257,000	658,000	334,000	277,000	406,000
Net deliveries from foreign stocks in Federal Reserve Bank of New York	do.	136,000	582,000	217,000	244,000	373,000
Stocks, Dec. 31:						
Industry 5/	do.	36,700	34,400	32,700 4/	(4/)	(4/)
Commodity Exchange (Comex) 6/	do.	46,500	78,500	49,100	45,400	20,700
Department of the Treasury 7/	metric tons	8,150	8,140	8,140	8,140	8,140
Volume of U.S. Gold Futures Trading 8/	do.	18,700	25,500	26,400	24,200	14,300
Department of the Treasury: 9/						
American Eagle gold coin	kilograms	11,100	21,800	10,900	13,900	10,700
Other Numismatic gold coins	do.	965	2,250	852	1,150	1,190
Consumption in industry and the arts	do.	110,000	91,400	76,100 4/	(4/)	(4/)
Apparent demand, refined 10/	do.	357,000	363,000	294,000 4/	(4/)	(4/)
Price: Average per troy ounce 11/		$345.00	$361.00	$385.00	$386.00	$389.00
Employment, mine and mill only 12/		14,800	14,700	14,100	14,700	16,900
World:						
Production, mine	kilograms	2,260,000 r/	2,260,000 r/	2,240,000 r/	2,220,000 r/	2,250,000 e/
Official bullion reserves 13/	metric tons	35,100	34,900	34,800	34,600	34,400

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ May include small quantities recovered by gravity methods.

3/ May include tailings, waste-ore dumps, and previously mined ore at some inactive mines.

4/ Data under review.

5/ Unfabricated refined gold held by refiners, fabricators, dealers, and the U.S. Department of Defense.

6/ Comex Division of the New York Mercantile Exchange.

7/ Includes gold in Exchange Stabilization Fund.

8/ Comex only.

9/ Sales to market in fiscal year 1990; thereafter, bullion disbursements to U.S. Mint coin programs. Fiscal year begins Oct. 1, of year prior to year indicated.

10/ Defined as refinery production from primary materials + refinery production from old scrap + net bullion flow to market from foreign stocks at the New York Federal Reserve Bank + net imports of bullion. Assumed to include gold held for investment purposes. Excludes gold contained in fabricated items, imported coins, and official monetary gold.

11/ Engelhard Industries quotation.

12/ Data from Mine Safety and Health Administration.

13/ Held by central banks and governments and international monetary organizations. Data from International Monetary Fund.

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TABLE 2
MINE PRODUCTION OF GOLD IN THE UNITED STATES, BY STATE 1/

(Kilograms)

State	1995	1996
Alaska 2/	4,410	5,020
Arizona	1,920	1,740
California	25,600 r/	23,800
Idaho	8,850	10,800
Montana	12,400	9,110
Nevada	210,000 r/	213,000
Other States 3/	53,700	57,500
Total	317,000 r/	321,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Production data collected by the State.

3/ Includes Colorado, New Mexico, South Carolina, South Dakota, Utah, Washington, and Wisconsin.

TABLE 3
TWENTY-FIVE LEADING GOLD-PRODUCING MINES IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of gold
1	Goldstrike	Eureka, NV	Barrick Gold Corp.	Gold ore.
2	Carlin Mines Complex	do.	Newmont Gold Co.	Do.
3	Bingham Canyon	Salt Lake, UT	Kennecott-Utah Copper Corp.	Copper ore.
4	Twin Creeks	Humboldt, NV	Santa Fe Pacific Gold Corp.	Gold ore.
5	Smokey Valley Common Operation	Nye, NV	Round Mountain Gold Corp.	Do.
6	Homestake	Lawrence, SD	Homestake Mining Co.	Do.
7	Jerritt Canyon (Enfield Bell)	Elko, NV	Independence Mining Co.	Do.
8	McCoy/Cove	Lander, NV	Echo Bay Mines	Do.
9	Lone Tree	Humboldt, NV	Santa Fe Pacific Gold Corp.	Do.
10	Bullfrog	Nye, NV	Barrick Gold Corp.	Do.
11	Mesquite	Imperial, CA	do.	Do.
12	McLaughlin	Napa, CA	Homestake Mining Co.	Do.
13	Florida Canyon	Lander, NV	Pegasus Gold Inc.	Do.
14	Cresson	Teller, CO	Cripple Creek & Victor	Do.
15	Getchell	Humboldt, NV	FirstMiss Gold Inc.	Do.
16	Cortez	Lander, NV	Placer Dome (U.S.) Inc.	Do.
17	Castle Mountain	San Bernardino, CA	Viceroy Gold Corp.	Do.
18	Ridgeway	Fairfield, SC	Kennecott Ridgeway Mining Co.	Do.
19	Denton-Rawhide	Mineral, NV	Kennecott Rawhide Mining Co.	Do.
20	Kettle River	Ferry, WA	Echo Bay Mines Ltd.	Do.
21	Golden Sunlight	Jefferson, MT	Placer Dome (U.S.) Inc.	Do.
22	Beartrack	Lehmi, ID	Meridan Gold Co.	Do.
23	Bald Mountain	White Pine, NV	Placer Dome Inc.	Do.
24	Hayden Hill	Lassen, CA	Amax Gold Inc.	Do.
25	Wharf	Lawrence, SD	Wharf Resources Ltd.	Do.

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TABLE 4
U.S. EXPORTS OF GOLD, BY COUNTRY 1/ 2/

Year and country	Ores and concentrates 3/		Dore and precipitates		Refined bullion		Total		Waste and scrap	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1995	352	$3,480	69,700	$841,000	277,000	$3,360,000	347,000	$4,210,000	82,400	$762,000
1996:										
Belgium	--	--	--	--	3,300	41,100	3,300	41,100	1,870	26,500
Canada	264	2,470	17,500	193,000	5,610	64,600	23,400	260,000	44,000	265,000
France	3	28	16	180	1	8	20	216	30,000	374,000
Germany	80	1,080	--	--	3,430	42,300	3,510	43,400	3,090	44,300
Hong Kong	--	--	--	--	8,180	100,000	8,180	100,000	--	--
Israel	--	--	59	368	--	--	59	368	--	--
Italy	1	6	--	--	40	410	41	416	330	4,130
Japan	--	--	505	6,190	5,080	63,200	5,580	69,400	58	691
Korea, Republic of	--	--	--	--	27,300	343,000	27,300	343,000	--	--
Mexico	1	13	353	4,460	4,300	46,100	4,660	50,600	--	--
Netherlands	--	--	2	29	797	9,870	799	9,900	--	--
Peru	--	--	--	--	420	4,990	420	4,990	--	--
Singapore	2	10	--	--	10	91	12	101	3	15
South Africa	--	--	--	--	1,990	24,600	1,990	24,600	--	--
Sweden	20	111	--	--	--	--	20	111	1,760	25,300
Switzerland	--	--	28,300	324,000	167,000	2,030,000	195,000	2,360,000	17	135
Taiwan	--	--	--	--	5,660	70,300	5,660	70,300	179	633
Turkey	--	--	--	--	227	2,770	227	2,770	--	--
United Arab Emirates	--	--	--	--	8	90	8	90	--	--
United Kingdom	3	12	18,200	168,000	172,000	2,160,000	191,000	2,330,000	8,620	112,000
Other	1	1	--	--	186	1,980	187	1,980	--	7
Total	375	3,730	65,100	696,000	406,000	5,010,000	471,000	5,710,000	89,900	853,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
3/ Includes base metal ores, concentrates, and matte destined for refining.

Source: Bureau of the Census.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY 1/ 2/

Year and country	Ores and concentrates 3/		Dore and precipitates		Refined bullion		Total		Waste and scrap	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
1995	5,020	$53,900	9,820	$92,600	111,000	$1,360,000	126,000	$1,510,000	14,400	$123,000
1996:										
Antigua and Barbuda	--	--	--	--	--	--	--	--	466	5,300
Argentina	--	--	--	--	170	2,090	170	2,090	--	--
Australia	--	--	--	--	350	4,340	350	4,340	--	
Austria	(4/)	(4/)	--	--	--	--	(4/)	(4/)	1	12
Bolivia	--	--	--	--	398	5,040	398	5,040	123	925
Brazil	--	--	--	--	18,300	229,000	18,300	229,000	--	--
Canada	151	1,190	1,770	16,900	77,500	972,000	79,400	990,000	1,420	11,000
Chile	--	--	2,460	15,100	7,360	92,200	9,810	107,000	419	6,480
China	--	--	--	--	--	--	--	--	58	640
Colombia	--	--	--	--	16,100	198,000	16,100	198,000	10	138
Costa Rica	7	92	--	--	100	1,040	107	1,130	784	7,190
Dominican Republic	--	--	--	--	690	5,540	690	5,540	4,380	29,600
Ecuador	--	--	263	3,240	444	5,480	707	8,720	183	1,080
Estonia	--	--	--	--	--	--	--	--	40	488
Germany	--	--	--	--	714	5,390	714	5,390	104	465
Guyana	--	--	--	--	53	625	53	625	--	--
Korea,Republic of	--	--	--	--	100	1,220	100	1,220	20	223
Malaysia	--	--	--	--	--	--	--	--	530	2,900
Mexico	3,240	40,100	6,700	70,200	8,020	99,500	18,000	210,000	1,840	11,900
Netherlands Antilles	--	--	--	--	1,960	24,300	1,960	24,300	--	--
Nicaragua	--	--	--	--	401	5,030	401	5,030	1	8
Panama	--	--	294	3,700	465	4,400	759	8,100	145	1,020
Peru	--	--	113	1,380	2,130	24,600	2,240	26,000	1,160	11,800
Philippines	--	--	7	175	--	--	7	175	299	2,470
Russia	62	775	2	20	70	576	134	1,370	44	396
South Africa	--	--	--	--	1,070	13,200	1,070	13,200	--	--
Suriname	--	--	--	--	618	8,480	618	8,480	--	--
Switzerland	--	--	60	901	3,500	44,400	3,560	45,300	2	29
Taiwan	--	--	--	--	--	--	--	--	193	1,730
Trinidad and Tobago	--	--	--	--	--	--	--	--	43	125
United Kingdom	--	--	267	5,890	803	10,000	1,070	15,900	14	103
Uruguay	--	--	--	--	1,040	12,300	1,040	12,300	159	3,080
Venezuela	--	--	--	--	873	10,300	873	10,300	44	514
Other	--	--	--	--	174	2,170	174	2,170	968	8,040
Total	3,460	42,200	11,900	117,000	143,000	1,780,000	159,000	1,940,000	13,000	102,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold excluded.
3/ Includes base metal ores, concentrates, and matte destined for refining.
4/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 6
GOLD: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country	1992	1993	1994	1995	1996 e/
Argentina	1,300 r/	937	937 r/	837 r/	850
Armenia e/	500	200	100	300 r/	250
Australia	243,000 e/	247,196	256,188	253,504	289,000
Belize e/	5	2	5	5	5
Bolivia	4,688	10,423	12,838	14,405	12,500
Botswana	165	192	248	86	90
Brazil 3/	85,862	74,219	70,535	62,424 r/	62,500
Bulgaria e/	2,000	2,000	2,000	2,000	2,000
Burkina Faso e/	5,400	5,000	4,000 r/	3,000 r/	4,000
Burundi e/	32	20	20	10	10
Cameroon e/	10	10	560 4/	1,000 r/	1,000
Canada	161,402	152,929	146,428	150,967 r/	164,136 p/
Central African Republic	155	153 r/	138 r/	120 r/ e/	90
Chile	33,774	33,638	38,786	39,180	39,600
China e/	125,000	130,000	132,000	140,000	145,000
Colombia	32,118	27,471 r/	20,762	21,160	22,064 4/
Congo e/	5 4/	5	5	5	5
Costa Rica e/	550	600	358 4/	500	500
Cote d'Ivoire	2,800	3,100	1,860 r/	1,983 r/	2,000
Dominican Republic	3,813	366	595	3,288	3,300
Ecuador e/ 5/	12,300	12,500	13,000	15,500	15,000
Eritrea	XX	XX	78	59	98 4/
Ethiopia 6/	2,224	3,387	2,370	4,500	5,000
Fiji	3,701	3,784	3,440	3,477 r/	4,790 4/
Finland	1,595	1,385	1,372	1,400 e/	2,100
France	2,910	2,155 r/	4,009	4,615 r/	4,500
French Guiana (Guyane) e/	2,140 4/	2,800 r/	2,270 r/	3,000 r/ 4/	3,000
Gabon e/ 7/	70	120	72	70	70
Georgia e/	1,500	1,000	600	500	500
Ghana	31,032	39,235	44,505	52,200 e/	50,100
Guatemala e/	32 4/	30	30	30	30
Guinea	2,113	1,500 r/	5,617	6,911 r/	7,000
Guyana	2,475	9,614	11,811	9,331 r/	12,441 4/
Honduras	163	111	106	110 e/	142 4/
India 8/	1,762	2,003	2,244	2,300 e/	2,500
Indonesia 9/	37,983	42,097	42,600	62,800 e/	65,000
Iran	500 e/	417	723	650	650
Japan	8,893	9,352	9,551	9,185	8,627 4/
Kazakstan e/ 10/	24,000	25,000	26,000	26,000	21,000
Kenya e/	20	154 4/	155	170	170
Korea, North e/	5,000	5,000	5,000	5,000	5,000
Korea, Republic of 8/	23,263	25,000 e/	12,332	13,418 r/	14,096 4/
Kyrgystan e/	1,000	1,000	3,000 r/	4,500 r/	5,000
Liberia e/	700	700	500	500	700
Madagascar e/	500	500	500	500	500
Malaysia	3,513	4,462	4,085	3,161	2,830 4/
Mali e/	5,700	5,500	5,500	7,800	8,000
Mexico	9,891	11,100	13,888	20,292	22,000
Mongolia e/	900	1,200	2,000	4,800	5,300
Mozambique	296	149	336	900 e/	1,000
Namibia	2,025	1,954	2,394	1,893 r/	2,015 4/
New Zealand	10,531	11,161	10,118 r/	12,132 r/	12,500
Nicaragua	1,322	1,240	1,073	1,600 e/	1,600
Niger e/	1	1	1	1	1
Panama e/	250 4/	255	245	1,100	1,200
Papua New Guinea	71,190	60,587	58,654 r/	51,701 r/	51,573 4/
Peru	24,242 r/	30,318 r/	46,313 r/ 11/	57,744 r/ 11/	64,786 4/ 11/
Philippines	25,609	21,155	27,059	27,144	20,000
Portugal e/	89	--	--	--	--
Romania e/	3,700	4,000 4/	4,000	4,000	4,000
Russia	146,000	149,500	146,600	132,170	120,000
Rwanda e/	1,000	1,000	100	100	50
Saudi Arabia	6,150	7,519	7,630	8,080	8,200
Senegal e/	(12/)	(12/)	(12/)	(12/)	(12/)

See footnotes at end of table.

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TABLE 6--Continued
GOLD: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country	1992	1993	1994	1995	1996 e/
Serbia and Montenegro	7,330	3,325	2,504 r/	3,040 r/	3,000
Sierra Leone 13/	92	157	125	4 r/	16 4/
Solomon Islands e/	25	20	5	1	1
South Africa	614,071	619,201	580,201	523,809 r/	497,583 4/
Spain	6,582	6,083	5,852	3,308 r/	3,000
Sudan e/	1,000	1,600	3,000 r/	3,700 r/	3,700
Suriname e/	300	300	300	300	300
Sweden	6,164	6,548	6,364	6,528 r/	6,500
Taiwan 8/	2	2	5	4 e/	4
Tajikistan e/	1,700	1,600	1,500	1,500	1,500
Tanzania	3,200	3,364	2,549	44	100
Turkey 14/	1,250	1,110	996 e/	1,000 e/	1,000
United States	330,000	331,000	327,000	317,000 r/	321,000
Uruguay e/	300	300	300	900	900
Uzbekistan e/	70,000	70,000	70,000	70,000 r/	72,000
Venezuela	7,553	8,899	10,094	7,259	12,000 p/
Zaire e/	9,000	1,500 r/	800 r/	600 r/	1,000
Zambia 15/	271	235	124	100 r/ e/	130
Zimbabwe	18,278	18,916	20,512	23,959 r/	24,772 4/
Total	2,260,000 r/	2,260,000 r/	2,240,000 r/	2,220,000 r/	2,250,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 15, 1997.

3/ Officially reported figures are as follows, in kilograms: Major companies: 1992--39,044; 1993--39,894; 1994--40,188; 1995--40,951 (revised); and 1996--41,000 (estimated). Garimpos 1992--37,000 (revised); 1993--30,000 (revised); 1994--30,347 (revised); 1995--21,473 (revised); and 1996--21,500 (estimated).

4/ Reported figure.

5/ Includes undocumented artisanal production.

6/ Year ending July 7 of that stated.

7/ Undocumented artisanal production.

8/ Refinery output.

9/ Excludes production from so-called people's mines, which may be as much as 18,000 kilograms per year, but includes gold recovered as byproduct of copper mining.

10/ Includes byproduct gold production. Primary gold production; in kilograms: 1994--14,483; 1995--18,200 (revised); and 1996--12,000.

11/ Includes documented production from small artisanal production.

12/ Less than 1/2 unit.

13/ Data are based on official exports and do not reflect gold moved through undocumented channels.

14/ Indicates byproduct of base metals.

15/ Year beginning Apr. 1 of that stated. Byproduct of copper production by Zambia Consolidated Ltd. only. Some additional artisanal production was reported, but data are insufficient to make reliable estimates.

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GRAPHITE

By Rustu S. Kalyoncu

Graphite, one of three known forms of carbon, occurs naturally in the Earth's crust in metamorphic rocks such as crystalline limestones, schists, and gneiss. It may be found in large crystalline hexagonal plates or disseminated in small flakes. A third class, so-called amorphous graphite is commonly found in microcrystalline form—thus the amorphous character— in weakly metamorphosed rocks, such as slates and shales. Artificial, or synthetic, graphite is manufactured on a large scale in electric furnaces using anthracite or petroleum coke as raw feed.

Graphite is an excellent thermal and electrical conductor. The high melting point of graphite, in absence of oxygen, 3,500° C, makes it suitable for a number of refractory applications. Excellent acid resistance and general chemical inertness make its use ideal in acid environments and other chemical applications. Graphite fibers—drawn from organic precursors, such as rayon, polyacrilonitrile and tar-pitch—are used as the reinforcing components in polymer composites.

Domestic graphite production information is developed by the U.S. Geological Survey from a voluntary survey of the U.S. producers. Out of 179 companies surveyed, 132 (74%) responded, an increase of 10% over the 1995 figures. Three plants no longer produce and were removed from the list. Synthetic graphite figures were not tabulated for 1996 as less than one-half of the producers responded to the survey.

There was no mining of natural graphite in the United States in 1996, thus all natural graphite is from foreign sources. Imports of natural graphite in 1996 were 53,400 metric tons at a value of $28.6 million. In 1996, the United States consumption of natural graphite was 32,400 tons at a value of $37.9 million, whereas the exports of manufactured goods from artificial and natural graphite were 92,500 tons, amounting to a dollar value of $68 million. (*See table 3.*)

Legislation and Government Programs

Total graphite inventories, excluding nonstock grade, reached 20,227 tons with a dollar value of about $5 million. This total amount was the inventory of stockpile natural graphite—Sri Lanka—as uncommitted inventory was reported to be 4,930 tons valued at $2.57 million, none of it authorized for disposal. Madagascar natural graphite inventories reached 14,400 tons with a $2.22 million value. *(See table 2.)*

Production

As was the case in previous years, there was no natural graphite mining in the United States in 1996, hence all the natural graphite processed was obtained through import channels. Principal import sources of natural graphite were Canada, China, and Madagascar. Mexico supplied the most of the amorphous graphite, and Sri Lanka providing the chip and lump graphite. In addition to the above four major countries, a number of other producers supplied various types and grades of graphite to the United States, among the more notable ones being Brazil, Germany, India, Japan, and South Africa. (*See table 6.*)

Graphite is mined from open pit and underground mine operations. Open pit operations are more economical and, thus, are preferred where the overburden is thin enough to remove. Madagascar mines are mostly open pit type. In the Republic of Korea, Mexico, and Sri Lanka, however, where the deposits are deep, underground mining is usually developed. Higher purity material is obtained by further crushing, grinding, and flotation steps.

Consumption

U.S. consumption of natural graphite declined significantly from 39,400 tons to 32,400 tons. (*See table 3.*) The largest decline is reflected in the amorphous grade which decreased 30%, from 18,800 to 13,100 tons. The refractories industry was the major consumer of crystalline graphite followed by brake lining manufacturers and lubricants. Refractory applications of graphite include both castable ramming and gunning mixtures, and shaped carbon-bonded brick. Carbon-magnesite brick containing crystalline flake graphite has applications in high-temperature corrosive environments, such as steel furnaces, ladles, and blast furnaces. Carbon-alumina linings are principally employed in continuous steel casting operations. Both magnesite- and alumina-carbon refractory bricks require fine particle size —100 mesh—and high purity—95% to 99% graphite.

Graphite as a substitute for asbestos in brake lining manufacture, with its lubricating character and high thermal conductivity, significantly reduces the heat generated due to friction, thus enhancing brake life. Other significant uses of graphite include the manufacture of long-life batteries furnishing low currents, steelmaking, rubber manufacture, and powder metallurgy. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical and more efficient. The three major uses, refractories, brake linings, and foundries accounted for over one-half the graphite consumed by the U.S. industry in 1996. (*See table 3.*)

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Prices

Prices of graphite have remained constant over the last 3 years. Crystalline flake graphite concentrates command higher prices than the amorphous (microcrystalline) type. Carbon content, flake and crystal size, size distribution, and ash content affect the price of graphite. Natural graphite prices are often subject to negotiations between the buyer and the seller, leading to a wide price range throughout the year. (*See table 4.*)

Foreign Trade

Total imports of natural graphite (flake crystalline and amorphous) decreased 12% from 1995 levels (from 60,700 tons in 1995 to 53,400 tons in 1996). Most imports were from Mexico, Canada, and Taiwan. Total exports, on the other hand, showed an increase of 2.1%, from 90,600 tons to 92,500 tons. (*See tables 5, 6, and 7.*)

World Review

World production of graphite is estimated to be 644,000 tons, showing a significant decrease from the 1995 value of 741,000 tons. The most significant decrease in production was in China. China, however, continued to be the leading producer, followed by India, North Korea, Brazil, and Mexico. These countries accounted for almost three-quarters of total world production of graphite. (*See table 8.*)

Brazil's dominant graphite producer, Nacional de Grafite Ltda., started a new flake graphite operation at Salto da Davisa in Minas Gerais, about 200 kilometers east of company's large graphite mining operations at Pedra Azul. Commissioning of the plant was expected to be late in 1996. Around 90% of the production will be targeted at export markets, particularly in North America (Industrial Minerals, 1996, p. 9).

Current Research and Technology

That new technologies for graphite products are being constantly developed is due, for the most part, to the advances in graphite thermal technology. The ability to refine and modify graphite and carbon products will be the key to future growth in the graphite industry. Innovative refining techniques have enabled the use of improved graphite in friction materials, electronics, foil, and lubrication applications (Hand, 1997, p. 34).

Some of the new application areas include electrically conductive asphalt for heated runways at airports and roadway bridges with capability of melting an inch of snow per hour. Such rate would prevent any accumulation of snow on the ground under almost any conditions.

Outlook

The general trend in materials and service is toward just-in-time (JIT) delivery. Customers would like to reduce their inventories to the lowest acceptable levels. They expect immediate delivery and appropriate technical assistance from the supplier. Joint cooperation with the allied industries is also a growing trend. In the past, suppliers developed the best product they could and went about trying to market it. Today, industries work together to engineer the best possible products to match the application requirements.

Industry trends that appear to be common to advances in graphite technology and markets include higher purity, consistency in specifications and supply sources. Production of higher purity graphite for specific applications, primarily through thermal processing and acid leaching appears to be the current trend.

The opportunities for the graphite industry and carbon products are numerous and promising. The need for high-tech graphite or carbon composites, be it in sporting goods manufacture or high temperature applications, will continue to fuel the development of high purity and high consistency products. Use of synthetic graphite in antilock break applications, where it is used as friction modifier to provide sufficient lubrication to prevent locking up of brakes, is another area where significant growth may take place.

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Other

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TABLE 1
SALIENT NATURAL GRAPHITE STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Production	metric tons	--	--	--	--	--
Apparent consumption 2/	do.	29,500	34,800	32,900	23,500	27,400
Exports	do.	20,200	17,400	20,300	37,300	26,000
Value	thousands	$12,200	$11,100	$13,100	$17,900	$14,600
Imports for consumption	metric tons	49,700	52,200	53,100	60,700	53,400
Value	thousands	$25,500	$29,900	$26,900	$30,100	$28,600
World: Production	metric tons	670,000	670,000 r/	552,000 r/	741,000 r/	644,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Domestic production plus imports minus exports.

TABLE 2
U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND
STOCKS OF NATURAL GRAPHITE IN 1996, BY TYPE

(Metric tons)

Type	Goal	National stockpile inventory
Madagascar crystalline flake	(1/)	14,400
Sri Lanka amorphous lump	12,200	4,930
Crystalline, other than Madagascar and Sri Lanka	(1/)	945
Nonstockpile-grade, all types	(1/)	126

1/ This commodity no longer has a goal.

Source: Defense National Stockpile Center, Inventory of Stockpile Materials as of Dec. 31, 1996.

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TABLE 3
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY USE 1/

(Thousand metric tons and thousand dollars)

End use	Crystalline		Amorphous 2/		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1995:						
Batteries	W	W	--	--	W	W
Brake linings	2,530	$3,580	5,980	$4,980	8,510	$8,570
Carbon products 3/	544	1,580	281	352	824	1,930
Crucibles, retorts, stoppers, sleeves, and nozzles	969	861	10	19	980	880
Foundries 4/	523	473	1,790	877	2,310	1,350
Lubricants	523	985	1,490	1,090	2,020	2,080
Pencils	1,100	1,100	642	600	1,740	1,700
Powdered metals	1,970	4,310	35	56	2,010	4,360
Refractories	5,770	5,310	4,180	3,550	9,950	8,860
Rubber	220	420	583	358	802	778
Steelmaking	125	178	1,100	422	1,220	600
Other 5/	6,330	11,600	2,760	2,310	9,080	13,900
Total	20,600	30,400	18,800	14,600	39,400	45,000
1996:						
Batteries	W	W	--	--	W	W
Brake linings	1,090	1,360	5,100	4,270	6,190	5,630
Carbon products 3/	472	1,410	376	365	847	1,770
Crucibles, retorts, stoppers, sleeves, and nozzles	898	824	7	14	906	839
Foundries 4/	560	478	724	346	1,280	824
Lubricants	434	942	1,620	1,440	2,050	2,380
Pencils	849	1,020	163	105	1,010	1,130
Powdered metals	511	1,170	19	42	530	1,210
Refractories	8,260	9,050	2,520	684	10,800	9,700
Rubber	168	326	584	336	753	662
Steelmaking	30	27	86	49	116	76
Other 5/	6,000	11,700	1,910	1,980	7,910	13,700
Total	19,300	28,300	13,100	9,630	32,400	37,900

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes mixtures of natural and manufactured graphite.

3/ Includes bearings and carbon brushes.

4/ Includes foundries (other) and foundry facings.

5/ Includes ammunition, antiknock and other compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, packings, paints and polishes, seed coating, small packages, soldering/welding, and other end-use categories.

TABLE 4
REPRESENTATIVE YEAREND GRAPHITE PRICES 1/

(Per metric ton)

Type	1995	1996
Crystalline large flake, 85% to 90% carbon	$450-$550	$450-$550
Crystalline medium flake, 85% to 90% carbon	330- 500	330- 500
Crystalline small flake, 80% to 95% carbon	270- 500	270- 500
Amorphous powder, 80% to 85% carbon	220- 300	220- 300

1/ Prices are normally "Cost, insurance, and freight" (c.i.f.) main European port.

Source: Industrial Minerals; No. 339, Dec. 1995, p. 64 and No. 351, Dec. 1996, p. 72.

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TABLE 5
U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY 1/ 2/

Country	Natural 3/		Artificial 4/		Total	
	Quantity (metric tons)	Value 5/	Quantity (metric tons)	Value 5/	Quantity (metric tons)	Value 5/
1995:						
Canada	3,560	$2,790,000	4,980	$9,810,000	8,540	$12,600,000
France	633	215,000	4,700	8,390,000	5,330	8,610,000
Japan	7,290	2,790,000	13,800	5,930,000	21,100	8,720,000
Korea, Republic of	393	323,000	8,680	4,530,000	9,070	4,860,000
Mexico	6,640	2,780,000	1,190	679,000	7,830	3,460,000
Netherlands	266	103,000	6,710	3,290,000	6,980	3,390,000
Taiwan	7,830	3,440,000	993	625,000	8,820	4,060,000
Other	10,600	5,370,000	12,300	15,200,000	22,900	20,700,000
Total	37,300	17,900,000	53,300	48,500,000	90,600	66,400,000
1996:						
Canada	3,830	3,290,000	6,770	9,410,000	10,600	12,700,000
France	324	151,000	8,280	8,830,000	8,610	8,980,000
Japan	811	642,000	17,700	8,200,000	18,500	8,860,000
Korea, Republic of	1,010	459,000	6,330	4,400,000	7,340	4,860,000
Mexico	9,250	3,510,000	3,950	2,130,000	13,200	5,640,000
Netherlands	366	186,000	7,690	3,470,000	8,050	3,650,000
Taiwan	2,390	1,520,000	1,100	1,110,000	3,490	2,630,000
Other	7,980	4,830,000	14,700	15,900,000	22,700	20,700,000
Total	26,000	14,600,000	66,600	53,400,000	92,500	68,000,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Numerous countries for which data were reported have been combined within the "Other" category under the "Country" list.

3/ Amorphous, crystalline flake, lump and chip and natural, not elsewhere classified. The applicable "Harmonized Tariff Schedule" (HTS) nomenclature title and code(s) are: "Natural graphite in powder or in flakes"/"Other," HTS Nos. 2504.10/90.0000.

4/ Includes data from the applicable "Harmonized Tariff Schedule" (HTS) nomenclatures: "Artificial graphite" and "Colloidal or semicolloidal graphite;" their respective HTS code Nos. are 3801.10.20.0000.

5/ Values are f.a.s.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY 1/ 2/

Country or territory	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude; high-purity; expandable		Amorphous		Total	
	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)
1995:										
Brazil	--	--	--	--	3,100	$4,030	--	--	3,100	$4,030
Canada	15,200	$10,300	--	--	124	30	--	--	15,400	10,300
China	3,450	1,720	--	--	9,930	3,600	2,920	$676	16,300	5,990
Germany	--	--	--	--	155	603	--	--	155	603
Hong Kong	--	--	--	--	(4/)	11	396	40	396	51
India	38	63	--	--	256	259	--	--	294	322
Japan	--	--	--	--	4,700	2,080	--	--	4,700	2,080
Madagascar	4,180	2,690	--	--	--	--	--	--	4,180	2,690
Mexico	--	--	--	--	--	--	14,500	2,080	14,500	2,080
Mozambique	--	--	--	--	--	--	--	--	--	--
South Africa	117	87	--	--	55	224	--	--	172	311
Sri Lanka	--	--	746	$455	--	--	--	--	746	455
Zimbabwe	581	278	--	--	--	--	--	--	581	278
Other 5/	149	502	--	--	41	439	40	29	230	970
Total	23,700	15,600	746	455	18,400	11,300	17,900	2,830	60,700	30,100
1996:										
Brazil	--	--	--	--	1,820	2,940	--	--	1,820	2,940
Canada	13,800	9,740	--	--	308	198	--	--	14,200	9,940
China	2,270	1,080	--	--	6,540	2,250	5,810	1,450	14,600	4,780
Germany	--	--	--	--	144	669	--	--	144	669
India	--	--	--	--	155	223	--	--	155	223
Japan	--	--	--	--	789	2,050	--	--	789	2,050
Madagascar	4,120	3,120	--	--	--	--	--	--	4,120	3,120
Mexico	--	--	--	--	--	--	14,800	1,980	14,800	1,980
Mozambique	472	464	--	--	--	--	--	--	472	464
South Africa	76	70	--	--	193	502	--	--	269	572
Sri Lanka	--	--	1,400	945	--	--	--	--	1,400	945
Zimbabwe	448	298	--	--	--	--	--	--	448	298
Other 5/	63	157	--	--	79	263	80	166	222	586
Total	21,300	14,900	1,400	945	10,000	9,100	20,700	3,600	53,400	28,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ The information framework from which data for this material were derived originated from Harmonized Tariff Schedule (HTS) base data.
3/ Customs values.
4/ Less than 1/2 unit.
5/ Includes Austria, Belgium (1995), Czech Republic (1995), France, Italy (1995), Kazakstan (1995), the Republic of Korea, the Netherlands, Poland, Russia (1996), Switzerland, Taiwan (1995), and the United Kingdom.

Source: Bureau of the Census, adjusted by the U.S. Geological Survey.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION
OF GRAPHITE ELECTRODES, BY COUNTRY 1/ 2/

Country	Quantity (metric tons)	Value 3/ (thousands)
1995:		
Canada	11,200	$30,900
Germany	2,420	7,430
Italy	8,230	14,700
Japan	8,020	21,700
Mexico	11,600	16,100
Other 4/	6,080	11,000
Total	47,500	101,800
1996:		
Canada	14,900	39,800
Germany	4,710	14,000
Italy	8,290	17,400
Japan	8,870	25,300
Mexico	14,600	22,600
Other 4/	8,000	16,000
Total	59,300	135,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The applicable "Harmonized Tariff Schedule" (HTS) code and nomenclature title are: (HTS 8545.11.0000); "Electric Furnace Electrodes."

3/ Customs values.

4/ Includes data for countries reflecting less than 1,000 metric tons for yearly imports.

Source: Bureau of the Census.

TABLE 8
GRAPHITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Argentina	20	-- r/	-- r/	-- r/	--
Austria	19,796	4,146	12,324	12,019	12,000
Brazil (marketable) 3/	29,414	29,472	35,965	36,000 e/	36,000
Canada (exports of natural graphite)	17,400	18,700	21,711	22,000 e/	23,000
China e/	300,000	310,000	183,000 r/	350,000	250,000
Czech Republic e/ 4/	XX	27,000	25,000	27,000 r/	25,000
Czechoslovakia 5/	20,000	XX	XX	XX	XX
Germany (marketable)	11,963	8,363	4,369 r/	5,000 r/	4,000
India (run-of-mine) 6/	72,996	82,398	93,597 r/	114,959 r/	120,000
Korea, North e/	38,000	38,000	38,000	40,000	40,000
Korea, Republic of	8,412	5,910	4,300	1,938 r/	2,000
Madagascar	8,910	11,182 r/ 7/	12,715 r/ 7/	16,522 r/ 7/	16,000
Mexico:					
Amorphous	30,500	42,600	43,000 e/	32,738 r/	34,000
Crystalline flake	985	960	1,000 e/	1,450 r/	1,500
Mozambique	--	--	--	4,100 e/	4,100
Namibia	200 e/	--	--	--	--
Norway e/	7,000	6,500	5,566 r/ 8/	3,000 r/	2,500
Romania	2,300	2,000 e/	2,335 r/	2,180 r/	2,200
Russia e/	15,000	10,000	8,000	8,000	6,000
Sri Lanka	3,307	5,163	2,950	3,000 e/	3,000
Tanzania	--	--	--	--	6,000
Turkey (run-of-mine) e/ 9/	20,978 8/	20,000	20,000	20,000	21,000
Ukraine e/	50,000	40,000	30,000	30,000	25,000
Zimbabwe	12,346	7,142	7,890	11,381 r/	11,000
Total	670,000	670,000 r/	552,000 r/	741,000 r/	644,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals and estimated data have been rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 13, 1997.

3/ Does not include the following quantities sold directly without beneficiation, in metric tons: 1992--8,957; 1993--9,960; 1994--9,670 (revised); 1995--10,000 (estimated); and 1996--10,000 (estimated).

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Dissolved Dec. 31, 1992.

6/ Indian marketable production is 10% to 20% of run-of-mine production.

7/ Exports. Source: United Nations, Department of International Economic and Social Affairs, Statistical Office.

8/ Reported figure.

9/ Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.

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GYPSUM

By Ronald F. Balazik

The United States continued to be the world leader in gypsum output and demand in 1996. Increased housing construction spurred domestic demand for gypsum building products during the year. The ownership of U.S. production facilities continued the consolidation trend of recent years as new companies entered the industry and others withdrew. For example, Georgia Pacific Corp. concluded its purchase of all gypsum mines and wallboard plants owned by the Canadian company, Domtar Inc. Also in 1996, three domestic producers planned to construct gypsum wallboard plants that would use only byproduct gypsum as feed material.

Data on the domestic gypsum industry are derived by the U.S. Geological Survey (USGS) from monthly, quarterly, and annual surveys of gypsum operations and from data provided by the Gypsum Association. The 1996 USGS survey, which canvassed more than 100 gypsum operations, had a response rate of 94%, accounting for virtually all domestic production. The output of producers that did not respond to the survey was estimated from annual canvasses of previous years and from other sources.

Production

The United States in 1996 continued to be the world's leading gypsum producer, accounting for 18% of global output. Domestic production of crude gypsum rose 5% during the year to 17.5 million metric tons, valued at $124 million. *(See table 1.)*

Crude gypsum was mined domestically by 30 companies at 61 mines in 20 States. The top producing States, in descending order, were Oklahoma, Texas, Iowa, Michigan, Nevada, California, and Indiana. These States, with 36 mines, produced more than one million tons each and together accounted for 73% of total domestic output. *(See table 2.)*

Leading producers were U.S. Gypsum Co., 11 mines; Georgia-Pacific Corp., 9 mines; National Gypsum Co., 7 mines; and Harrison Gypsum Inc., 3 mines. These companies produced almost two-thirds of total U.S. crude gypsum. The 10 largest gypsum mines in the United States accounted for 39% of domestic output in 1996. These mines, owned by five companies, had an average output of 670,000 tons.

Gypsum was "calcined" (that is, partially dehydrated by heating) at 67 plants operated by 10 companies in 28 States during 1996, principally to produce feedstock for wallboard and plaster plants. The quantity and value of calcined output increased significantly relative to production in the preceding year. Leading States were (in descending order) Iowa, California, Texas, Florida, Oklahoma, and New York. These States, with 25 plants, accounted for 43% of national output. *(See table 3.)*

Companies with the most calcining plants were U.S. Gypsum Co., 20; National Gypsum, 18; Georgia-Pacific, 17; and Celotex Corp., 4. These companies produced more than 80% of national output. The largest 10 calcining plants in the United States accounted for more than one-third of domestic production in 1996. These plants, owned by five companies, had an average output of almost 700,000 tons.

In addition to mined gypsum, byproduct gypsum is generated by various industrial processes and by flue gas desulfurisation (FGD) at many coal-burning electric powerplants. Byproduct gypsum is used principally for wallboard manufacturing, agriculture, roadbase, and fill material. In response to USGS surveys, 10 companies operating 14 plants in 11 States reported sales of 2.4 million tons of byproduct gypsum in 1996. Byproduct gypsum sales by the companies have been increasing in recent years. In addition to these companies, about 60 domestic coal-fired electric utilities generated 21.5 million tons of FGD gypsum during 1996, 15% more than in 1995. Only 1.5 million tons of the FGD material generated in 1996 was used, primarily for wallboard production (American Coal Ash Association, 1997).

During 1996, 13 U.S. companies manufactured gypsum wallboard products at 75 plants. Total production capacity at the plants increased slightly during the year to 26.1 billion square feet (2.42 billion square meters). Wallboard shipments totaled 24 billion square feet (2.19 billion square meters), or 91% of production capacity.

Three domestic gypsum producers plan to build new wallboard plants designed to use FGD gypsum from electric utilities. The plants will be constructed in Bridgeport, AL, Clarksville, TN, and Shippingsport, PA. All of the plants are scheduled to be operational by the year 2000 (Drake, 1997; The McIlvaine Co., 1997).

Consumption

A 9% growth in housing starts during 1996 (Bureau of the Census, 1997) stimulated gypsum consumption during the year. Apparent U.S. consumption of gypsum (defined as mine output plus net imports, industry stock changes, and byproduct use) reached at least 26.5 million tons during the year; consumption may have been greater if unreported byproduct gypsum was utilized. Domestic sources (mining plus 3.9 million tons of byproduct gypsum) met 81% of domestic consumption requirements; remaining needs were satisfied with imports.

Gypsum output is categorized as either calcined or

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uncalcined. About 19 million tons of gypsum was calcined for use in wallboard and plaster products during 1996, accounting for 71% of total gypsum use in the United States. Uncalcined gypsum, used for portland cement production, agriculture, and filler material, accounted for virtually all the remaining consumption. *(See table 4.)*

Most of the calcined gypsum consumed in wallboard manufacturing during 1996 (86%) was used to produce regular 1/2-inch wallboard and fire-resistant type X wallboard. Mobile-home board, water/moisture-resistant board, lath, veneer base, and sheathing composed most of the balance. *(See table 5.)* The leading sales areas for these gypsum wallboard products were (in descending order) the South Atlantic, the Eastern North-Central, the Western South-Central, and the Pacific regions of the United States.

More than two-thirds of the uncalcined gypsum consumed in the United States during 1996 was used in portland cement production, while the remainder was used primarily for agricultural purposes. Gypsum is added to cement to retard the setting time; gypsum composes about 2% to 5% of cement output (Dutton, 1997). Finely ground gypsum rock is used in agriculture to neutralize alkaline soils, to improve the permeability, and to provide sulfur and catalytic support for maximum fertilizer benefits. Small amounts of pure gypsum also are employed in a wide range of industrial uses, including glassmaking, papermaking, and pharmaceutical applications.

Stocks

At yearend 1996, stocks of crude gypsum at mines and calcining plants totaled 4.5 million tons. Reported stocks had been 2.1 million tons at the beginning of the year.

Prices

The average values per ton (f.o.b. mine or plant) reported by producers for 1996 decreased slightly to $7.10 for crude gypsum and increased 17% to $20.27 for calcined gypsum. The average per-ton values of gypsum for plaster, wallboard, and uncalcined products were $148, $102, and $12, respectively. Delivered prices for uncalcined gypsum to agricultural markets and cement plants reportedly ranged from $13 to $40 per ton, depending on transport mode and distance shipped (Glasscock, 1996).

Yearend prices for comparable gypsum wallboard products in 20 U.S. cities varied considerably. Regular 1/2-inch wallboard prices ranged from $93 per 1,000 square feet (928 square meters) in Cincinnati to $210 in Minneapolis. The average yearend price for the 20 cities was $155 per 1,000 square feet, about $4 more than at the beginning of the year (Stussman, 1996).

Foreign Trade

The United States is a world leader in the international trade of gypsum and gypsum products; in 1996, crude gypsum was imported from 12 countries and gypsum wallboard was exported to 62 countries. Only a small amount of crude gypsum is exported by the United States. *(See tables 6 and 7.)*

Net imports of crude gypsum, which decreased slightly during the year, accounted for almost one-third of apparent consumption. Much of this import dependance can be attributed to the lack of adequate gypsum resources near large East Coast markets. Canada and Mexico, the major U.S. sources of crude gypsum imports, primarily supplied wallboard plants in coastal markets; most imports from Canada went to East Coast plants, while Mexican sources chiefly served the West Coast. Foreign subsidiaries of some domestic gypsum companies produced much of the gypsum that was imported for the wallboard plants. Smaller gypsum imports were used for portland cement production as well.

Wallboard exports totaling about 92 million square feet (8.5 million square meters) and valued at $23 million were shipped to Asia, Europe, and Latin America. Wallboard imports were about 860 million square feet (80 million square meters), valued at $89 million. The imports were from four countries, but virtually all came from Canada and Mexico.

World Review

More than 90 countries produce gypsum throughout the world. *(See table 8.)* Global production of gypsum is estimated to have reached about 100 million tons in 1996. This estimate may be low because in some countries output that is used by the gypsum producers themselves to make other products is not reported. Moreover, production from small deposits in developing countries is intermittent and frequently unreported.

As a low-value, high-bulk commodity drawn from deposits widely distributed throughout the world, gypsum tends to be consumed within the many countries that mine it. It is estimated that less than 20% of world gypsum production enters international trade. Nevertheless, a few countries are significant exporters. Canada and Mexico, for example, export much of their output to large, nearby markets in the United States.

Industrialized nations such as the United States use gypsum primarily for wallboard products. However, in developing countries (particularly those of Asia) most gypsum is utilized by cement plants.

Estimated world production capacity for gypsum wallboard in 1996 was approximately 54 billion square feet (5 billion square meters) at about 240 plants worldwide (Mields, 1996). Most of this capacity was in the United States (45%), Western Europe (20%), and Asia (20%). Plans for the construction of new wallboard plants in several countries; for example, China, Germany, and the United States) were announced in 1996 (McCaffrey, 1996; Tradeship Publications, 1997).

Outlook

Market demand for gypsum in the United States is projected to increase approximately 2% per year in the remaining 1990's (Weiss, 1997). Domestic gypsum prices are expected to remain

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stable during the forecast period. World demand will be driven primarily by the construction industry, particularly in the United States where more than 90% of the gypsum currently consumed is used for gypsum wallboard products, building plasters, and the manufacture of portland cement. In developing nations, the rate of gypsum use for wallboard will grow as new wallboard plant capacity is added.

The utilization of byproduct gypsum generated by industrial processes and the desulfurization of electric powerplant emissions will accelerate as new wallboard plants that use byproduct feedstock are opened. However, more favorable economic circumstances that support byproduct gypsum as a replacement for natural gypsum (for example, rising ore costs) are necessary to encourage further substitution.

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[1]Prior to January 1996, published by U.S. Bureau of Mines.

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TABLE 1
SALIENT GYPSUM STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Active mines and plants 2/	109	112	108	115	111
Crude:					
Mined	14,800	15,800	17,200	16,600	17,500
Value	$101,000	$107,000	$115,000	$121,000	$124,000
Imports for consumption	7,180	7,390	8,470	8,160	8,050
Byproduct gypsum sales	630	846	950	1,220	2,420
Calcined:					
Produced	15,100	15,200	16,700	16,700	18,800
Value	$250,000	$272,000	$288,000	$290,000 r/	$381,000
Products sold (value)	$1,350,000 3/	$1,780,000 3/	$2,630,000 3/	$2,120,000	$2,380,000
Exports (value)	$97,000	$77,600	$73,400	$75,100	$81,400
Imports for consumption (value)	$96,000	$111,000	$141,000	$166,000	$196,000
World: Production	98,800 r/	97,100 r/	96,200 r/	96,500 r/	99,700 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

3/ Does not include value of plasters sold.

TABLE 2
CRUDE GYPSUM MINED IN THE UNITED STATES, BY STATE OR REGION 1/

	1995			1996		
	Active mines	Quantity (thousand metric tons)	Value (thousands)	Active mines	Quantity (thousand metric tons)	Value (thousands)
Arizona and New Mexico	5	880	$6,332	6	1,200	$8,875
Arkansas, Kansas, Louisiana	5	1,490	11,400	5	1,580	12,400
California, Nevada, Utah	12	3,000	16,600	13	3,310	20,700
Colorado, South Dakota, Wyoming	5	756	5,380	7	883	6,720
Indiana, New York, Ohio, Virginia	5	2,000	19,300	5	1,950	19,200
Iowa	6	2,240	13,800	6	2,090	12,800
Michigan	5	1,510	14,900	5	1,590	14,400
Oklahoma	8	2,380	17,000	7	2,690	16,500
Texas	6	1,880	16,200	6	2,240	12,100
Total	57	16,600	121,000	60	17,500	124,000

1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 3
CALCINED GYPSUM PRODUCED IN THE UNITED STATES, BY STATE OR REGION 1/

	1995			1996		
	Active plants	Quantity (thousand metric tons)	Value (thousands)	Active plants	Quantity (thousand metric tons)	Value (thousands)
Arizona, Colorado, New Mexico, Utah	5	1,040	$8,400	5	1,150	$9,340
Arkansas, Louisiana, Oklahoma	7	1,990	24,100	7	2,240	30,900
California	5	1,360	23,400	5	1,450	66,000
Delaware, Maryland, North Carolina, Virginia	6	1,320	33,300	6	1,420	84,600
Florida	3	1,180	28,000	3	1,290	30,900
Georgia	3	506	8,860	3	638	15,700
Illinios, Indiana, Kansas	6	1,400	23,500	6	1,270	21,700
Iowa	5	1,470	22,400	5	1,730	20,900
Massachusetts, New Hampshire, New Jersey	5	1,100	23,500	5	1,050	23,200
Michigan	4	601	13,400	4	544	12,400
Nevada	4	1,180	13,600	3	805	7,060
New York	4	1,020	22,000	4	1,010	18,100
Ohio	3	425	8,940	3	2,250	9,300
Texas	5	1,290	20,100	5	1,320	18,900
Washington and Wyoming	4	859	16,600	3	636	12,000
Total	69	16,700	290,000	67	18,800	381,000

1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 4
GYPSUM PRODUCTS (MADE FROM DOMESTIC, IMPORTED, AND BYPRODUCT GYPSUM) SOLD OR USED IN THE UNITED STATES, BY USE 1/

(Thousand metric tons and thousand dollars)

	1995		1996	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland cement	4,680	54,600	5,310	59,000
Agriculture and miscellaneous 2/	2,140	33,600	2,280	35,000
Total	6,810	88,200	7,600	94,000
Calcined:				
Plasters	806	89,300	653	96,500
Prefabricated products 3/	18,700	1,950,000	21,200	2,180,000
Total calcined	19,500	2,030,000	21,900	2,280,000
Grand total	26,300	2,120,000	29,500	2,380,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes byproduct gypsum.
3/ Includes weight of paper, metal, or other materials and some byproduct gypsum.

TABLE 5
PREFABRICATED GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES 1/

	1995			1996		
Product	Thousand square feet	Thousand metric tons 2/	Value (thousands)	Thousand square feet	Thousand metric tons 2/	Value (thousands)
Lath:						
3/8 inch	6,100	4	$1,250	5,360	3	$1,160
1/2 inch	57	(3/)	11	76	(3/)	--
Other	--	--	--	9,510	10	2,470
Total	6,160	4	1,270	14,900	13	3,640
Veneer base	394,000	352	36,300	467,000	458	41,500
Sheathing	314,000	266	36,800	346,000	319	42,000
Regular gypsumboard:						
3/8 inch	839,000	661	63,400	868,000	785	75,600
1/2 inch	10,600,000	8,440	928,000	11,400,000	9,540	1,010,000
5/8 inch	1,510,000	1,290	80,500	1,750,000	1,750	100,000
1 inch	169,000	156	31,300	186,000	199	38,100
Other 4/	195,000	154	24,000	347,000	328	31,700
Total	13,300,000	10,700	1,130,000	14,500,000	12,600	1,250,000
Type X gypsumboard	6,080,000	5,510	486,000	5,840,000	5,790	556,000
Predecorated wallboard	84,200	75	27,300	89,600	87	30,700
5/16-inch mobile home board	1,260,000	943	139,000	1,630,000	1,200	156,000
Water-moisture-resistant board	880,000	740	75,700	703,000	640	88,100
Other	139,000	116	14,100	121,000	103	13,100
Grand total	22,500,000	18,700	1,950,000	23,700,000	21,200	2,180,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes weight of paper, metal, or other materials.
3/ Less than 1/2 unit.
4/ Includes 1/4, 7/16, and 3/4-inch gypsumboard.

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TABLE 6
IMPORTS FOR CONSUMPTION OF CRUDE GYPSUM, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Australia	33	272	3	72
Bahamas, The	298	1,490	163	759
Canada 2/	5,560	43,800	5,490	45,200
China	(3/)	4	--	--
Dominican Republic	(3/)	8	(3/)	31
Hong Kong	(3/)	4	(3/)	2
Italy	(3/)	2	(3/)	1
Japan	(3/)	22	(3/)	44
Mexico	1,890	11,600	1,860	11,700
Philippines	--	--	(3/)	17
Spain	379	2,730	541	4,400
United Kingdom	(3/)	95	1	251
Total	8,160	60,000	8,050	62,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes anhydrite.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 7
SUMMATION OF U.S. GYPSUM AND GYPSUM PRODUCTS TRADE DATA 1/

(Thousand metric tons and thousands dollars)

Year	Crude 2/		Plasters 3/		Boards 4/		Other 5/	Total
	Quantity	Value	Quantity	Value	Quantity	Value	Value	value
Exports:								
1995	79	4,240	159	23,900	64	17,300	29,600	75,100
1996	136	6,120	142	25,800	80	22,800	26,700	81,400
Imports for consumption:								
1995	8,160	60,000	8	1,520	560	64,400	40,300	166,000
1996	8,050	62,500	11	2,220	748	89,300	42,400	196,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import and export data are for "Gypsum; anhydrite," Harmonized Tariff Schedule 2520.10.0000.
3/ Import and export data are for "Plasters, " Harmonized Tariff Schedule 2520.20.0000.
4/ Import and export data are for " Boards, sheets, panels, tiles and similar articles, not ornamented: Faced or reinforced with paper or paperboard only," Harmonized Tariff Schedule 6809.11.0000.
5/ Import and export data are for "Boards, sheets, panels, tiles, and similar articles, not ornamented: other, " Harmonized Tariff Schedule 6809.19.000 and "Other articles," Hamonized Tariff Schedule 6809.90.0000.

Source: Bureau of the Census.

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TABLE 8
GYPSUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Afghanistan e/	3	3	3	3	3
Algeria e/	150	150	150	175	175
Angola e/	57	50	50	50	50
Argentina	514	519	515 r/	532 r/	520
Australia e/	2,000	2,000	2,000	2,000	2,000
Austria 3/	792	876	1,069	873 r/	900
Azerbaijan e/	100	75	60	50	55
Bhutan	25	20 e/	45	52	40
Bolivia	6 e/	4 e/	1	2	55 4/
Bosnia and Herzegovina e/	50	30	30	30	30
Brazil 3/	888	874	789	935 r/	935
Bulgaria 3/	125	143	-- r/	163 r/	169 4/
Burma	31	28	38	35	38
Canada 3/	7,566	7,880	8,500	8,055 r/	8,333 p/
Chile	424	511	552	550 e/	550
China e/	11,000	10,600	6,820 r/	7,340 r/	8,000
Colombia	671	439	450	450 r/ e/	450
Croatia e/	50	50	50	97 r/	86 4/
Cuba e/	125	125	125	130	130
Cyprus	35	40	89	90 e/	90
Czech Republic 5/	XX	560 e/	591	542	550
Czechoslovakia e/ 6/	600	XX	XX	XX	XX
Dominican Republic e/	83 4/	85	83	85 r/	85
Ecuador e/	-- r/	-- r/	-- r/	-- r/	--
Egypt 3/	1,425	1,199	1,200 e/	1,200 e/	1,200
El Salvador e/	5	5	5	5	5
Eritrea	XX	XX	(7/)	(7/)	(7/) 4/
Ethiopia e/ 3/ 8/	3	3	31	54	50
France 3/	5,160	5,000 e/	5,200	4,800 r/	5,000
Germany (marketable) 3/	4,353	2,678	2,264	2,500 r/	2,500
Greece 3/	452	446 r/	454	450 e/	450
Guatemala	73 r/	75 r/ e/	89 r/	90 r/ e/	90
Honduras e/	26	26	26	26	26
Hungary 3/	120 r/ e/	125 r/	150 r/ e/	198 r/	190
India	1,301	1,805	1,730 r/	1,739 r/	1,700
Indonesia	400 e/	2	1	1	1
Iran 9/	8,253	7,799	8,430	8,230	8,300
Iraq e/ 10/	380	450	450	450	450
Ireland	343	318	367 r/	406 r/	400
Israel	48	48	48 e/	48 e/	48
Italy	835 r/	1,200 e/	1,361 r/	1,200 e/	1,200
Jamaica	145	152	204	208	210
Japan	4,322	3,953	3,873	5,334 r/	5,350
Jordan	83	195	193	190 e/	190
Kenya e/ 3/	36	36	36	36	36
Laos e/	80 4/	80	85	85	85
Latvia	350 e/	300 e/	61	81 r/	77 4/
Lebanon e/	2	2	2	2	2
Libya e/	180	160	160	160	160
Luxembourg e/ 3/	(7/)	(7/)	(7/)	(7/)	(7/)
Macedonia e/	30	30	25	25	25
Mali e/	1	1	1	1	1
Mauritania	3	3	--	--	--
Mexico 3/	5,160	5,340	5,040	4,854 r/	5,262 4/
Moldova	75 e/	25 e/	15	14	14
Mongolia e/	25	25	25	25	25
Morocco e/	450	450	450	450	450
Namibia e/	(7/)	(7/)	(7/) 4/	--	--
Nicaragua 3/	9	11	11 e/	13 e/	13
Niger e/	2 4/	2	2	2	2
Pakistan	462	535	607	314	504 4/
Paraguay e/	5	5	5	5	5

See footnotes at end of table.

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TABLE 8--Continued
GYPSUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Peru e/	35	35	35	35	35
Philippines e/ 3/	25 4/	25	25	25	25
Poland 3/	843 r/	832	1,055	1,023 r/	1,100
Portugal 3/	417	459	450 e/	450 e/	450
Romania	800 e/	100	124	111 r/	72 4/
Russia e/	1,800	1,500	1,200	1,200	850
Saudi Arabia	269	327	375 e/	375 e/	375
Serbia and Montenegro	48	--	40	40	44 4/
Sierra Leone e/	4	4	4	(7/) r/	(7/)
Slovakia 3/ 5/	XX	75	122	131 r/	110
Slovenia e/	10	10	10	10	10
Somalia e/	2	2	2	2	2
South Africa	334	284	304	288	317 4/
Spain 3/	6,760	7,250	7,250 e/	7,500 e/	8,000
Sudan e/ 3/	10	10	10	10	5
Switzerland e/	200	200	200	200	200
Syria	234	300	302	336 r/	340
Taiwan	2	3	3	3 e/	3
Tajikistan e/	500	400	300	200	150
Tanzania 3/	27	1	8	1	1
Thailand	7,111	7,455	8,140	8,533	8,900
Tunisia e/	650	650	650	700	700
Turkey	278	493	597 r/	600 r/ e/	600
Turkmenistan e/	250	200	150	216 r/ 4/	170 4/
United Arab Emirates e/	95	95	95	90	90
United Kingdom e/ 3/	3,000	2,500	2,500	2,000 r/	2,000
United States 11/	14,800	15,800	17,200	16,600	17,500 4/
Uruguay e/	145	145	145	145	145
Venezuela	175	224	135	135 e/	135
Vietnam e/	30	30	30	30	30
Yemen	80	90	80 e/	80 e/	80
Zambia e/ 10/ 12/	13	13	13	13	13
Total	98,800 r/	97,100 r/	96,200 r/	96,500 r/	99,700

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 15, 1997.

3/ Includes anhydrite.

4/ Reported figure.

5/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

6/ Dissolved Dec. 31, 1992.

7/ Less than 1/2 unit.

8/ Data are for years ending July 7 of that stated. Reported in cubic meters and estimated at mean weight of 1.5 tons per cubic meter. Data for 1992-93 probably do not include production for cement manufacture (normally 3%-5% of finished cement, equivalent of an additional 10,000 to 15,000 tons per year).

9/ Data are for years beginning Mar. 21 of that stated.

10/ For cement production only. Information is insufficient to formulate reliable estimates for output for other uses (plaster, mortar, etc.).

11/ Excludes byproduct gypsum.

12/ Data are for years beginning Mar. 1 of that stated.

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HELIUM

By Joseph B. Peterson[1]

Grade-A helium (99.995% or better) sales volume in the United States by private industry and the Bureau of Land Management (BLM) was 71.9 million cubic meters (2,592 million cubic feet) in 1996.[2] Grade-A helium exports by private producers were 22.8 million cubic meters (822 million cubic feet) for total sales of 94.6 million cubic meters (3,411 million cubic feet) of U.S. helium, about 1.5% less than that in 1995. The BLM price for Grade-A helium, f.o.b. plant, was $1.983 per cubic meter ($55 per thousand cubic feet), and bulk liquid helium was $2.524 per cubic meter ($70 per thousand cubic feet) on January 1, 1996, with additional costs for container services and rent.

Legislation and Government Programs

The Federal Helium Program was established to provide all Federal agencies with current and estimated future helium needs to carry out Government programs authorized and funded by Congress. The BLM's major helium customers were the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE).

In March 1996, Helium Operations was transferred to the BLM from the U.S. Bureau of Mines, which was closed in January 1996.

On October 9, 1996, the President signed the Helium Privatization Act of 1996 (Public Law 104-273). This legislation directs Helium Operations to discontinue production and sale of refined helium by April 9, 1998. Key components of the legislation are as follows:

- Cease production and sales of Grade-A helium not later than April 9, 1998, requiring Federal customers to purchase helium from private industry;
- Dispose of all helium production, refining, and sales-related assets not later than 24 months after helium refinery closing;
- Sell Federal reserves of crude helium in excess of 600 million cubic feet on or before January 1, 2005, and continuing to January 1, 2015. As of December 31, 1996, approximately 30 billion cubic feet of crude helium are to be sold;
- Continue operation of the helium storage system that includes the storage field and pipeline system for storage and distribution of both Government and privately owned crude helium; and
- Continue collection of helium royalty and fee sales for helium extracted from Federal lands.

While the legislation provides a maximum 18-month timeline to discontinue production and sales operations, the determining factor shall be the Federal demand for refined helium. If helium sales decrease significantly (i.e., NASA finds an alternate source for helium), then production would cease prior to April 9, 1998.

Production

In 1996, 20 privately owned domestic helium plants were operated by 14 companies. Thirteen of the privately owned plants and the BLM plant extracted helium from natural gas. All extraction plants except two use cryogenic extraction processes. The volume of helium recovered from natural gas increased 2% over that of last year, while total sales of U.S.-produced helium decreased 1.5% in 1996 from those of the previous year. All natural gas processed for helium recovery came from gasfields in Colorado, Kansas, Oklahoma, Texas, Utah, and Wyoming. Eleven private plants and the BLM plant purified helium this year. Pressure-swing adsorption is used for helium purification at 9 of the 11 private helium plants and at the BLM plant. The BLM also used cryogenic purification for backup. The BLM and eight private plants that produce Grade-A helium also liquefy helium. The plant operators and locations are Air Products Helium Inc., Hansford County, TX, and Liberal, KS; BOC Gases Inc., Otis, KS; Exxon Co., U.S.A., Shute Creek, WY; CIG Co., Keyes, OK, and Lakin, KS; Praxair, Inc., Bushton and Ulysses, KS; and Unocal, Moab, UT. Nitrotec's helium plants near Burlington, CO, and near Cheyenne Wells, CO, produce Grade-A helium but do not liquefy it. (*See tables 1, 2, and 3, and figures 1 and 2.*)

Domestic production data for helium were developed by the BLM from records of its own operations as well as the High Purity Helium Survey, a single, voluntary canvass of private U.S. operations. Of the seven operations to which a survey request was sent, 100% responded, and those data plus data from BLM operations represent 100% of the total helium sales and recovery shown in table 2.

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[1]Chief, Plant Process and Environmental Engineering, BLM Helium Operations, Amarillo, TX.

[2]All metric helium volumes herein reported are at 101.325 kilopascals absolute (14.696 psia) and 15° C (59° F). Helium volumes, reported in parentheses following metric units, are measured in cubic feet at 14.7 psia and 70° F = 27.737 cubic meters at 101.325 kilopascals absolute and 15° C. One cubic meter at 101.325 kilopascals nad 15° C = 36.053 cubic feet at 14.7 psia and 70° F.

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Domestic measured and indicated helium resources as of January 1, 1994, (the latest figures available) are estimated to be 13 billion cubic meters (469 billion cubic feet). The resources include measured reserves and indicated resources estimated at 6.7 billion cubic meters (241 billion cubic feet) and 0.9 billion cubic meters (32 billion cubic feet), respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included nearly 1 billion cubic meters (34 billion cubic feet) stored by the BLM in the helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 1.3 billion cubic meters (46 billion cubic feet). Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 3.9 billion cubic meters (140 billion cubic feet). Approximately 4.4 billion cubic meters (157 billion cubic feet) or 91% of the domestic helium resources under Federal ownership are in the Riley Ridge area and the Church Buttes Field in Wyoming and in the Cliffside Field in Texas.

Most of the domestic helium resources are in the midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 102 gasfields in 11 States. About 86% of these reserves is contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; the Panhandle and Cliffside Fields in Texas; and the Riley Ridge area in Wyoming. The BLM analyzed a total of 70 natural gas samples from 13 States during 1996 in conjunction with its program to survey and identify possible new sources of helium.

Consumption

The major domestic end uses of helium were cryogenics, welding, and pressurizing and purging. Minor uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. (*See figure 3.*) The Pacific and Gulf Coast States were the principal areas of helium consumption.

The BLM sales to Federal agencies and their contractors totaled 6.07 million cubic meters (219 million cubic feet) in 1996. Direct helium purchases by DOD, NASA, and DOE constituted most of the BLM Grade-A helium sales. Most remaining helium sales to Federal agencies were made through BLM contract distributors, who purchased equivalent volumes of BLM helium under contracts described in the Code of Federal Regulations (30 CFR 602). Some of the contract distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at lower freight charges by using the contractors' existing distribution systems.

Estimated 1996 domestic consumption by end use was based on a 1995 domestic end-use survey conducted to determine the trends in helium usage. The information from that survey showed that welding, pressure-purging, lifting gas, leak detection, and inert atmosphere applications continue to be the leading usages of gaseous helium. Magnetic resonance imaging applications dominated liquid helium usage. (*See figure 3.*)

Stocks

The volume of helium stored in the BLM helium conservation storage system, including the conservation pipeline network and Cliffside Field, totaled 970 million cubic meters (35.0 billion cubic feet) at yearend. The storage system contains crude helium purchased under contract by the BLM from 1962 to 1973 and privately owned helium stored under contract. Excess private helium is extracted from natural gas supplying fuel markets and stored by the BLM under contract. This privately owned crude helium is returned to the owners as needed for purification to supply private demand. During 1996, 36.7 million cubic meters (1,324 million cubic feet) of private helium was delivered to the BLM's helium conservation storage system and 21.2 million cubic meters (765 million cubic feet) was withdrawn for a net increase of 15.5 million cubic meters (558 million cubic feet) of private helium in storage. (*See table 4.*)

Transportation

All Grade-A gaseous helium sold by the BLM was shipped in modules (large gas cylinders), special railway tankcars, or highway tube semitrailers from either the Amarillo Helium Plant or the Exell Helium Plant located at Masterson, TX. The BLM liquid helium was shipped in dewars and semitrailers from the Exell plant. Private producers and/or distributors shipped helium predominantly as a liquid in semitrailers. These semitrailers delivered the liquid helium to distribution centers where some of it was gasified and compressed into trailers and small cylinders for delivery to the end user. The remaining liquid helium was sold as bulk liquid or repackaged in dewars of various sizes for delivery.

Prices

The BLM price for Grade-A helium, f.o.b. plant, was $1.983 per cubic meter ($55 per thousand cubic feet) and bulk liquid helium was $2.524 per cubic meter ($70 per thousand cubic feet) on January 1, 1996, with additional costs for container services and rent.

Foreign Trade

Exports of Grade-A helium, all by private industry, decreased by 17.7% in 1996 to 22.8 million cubic meters (822 million cubic feet). (*See table 3.*) About 54% of the U.S. helium exports went to Asia, with Japan receiving about 84% of the Asian export. About 18% of the exported helium was shipped to Europe. Belgium, France, Germany, and the United Kingdom, collectively, received about 95% of the European exports. Other exports were as follows: about 13% to North America; about 4% to Australia-New Zealand, 2% to the Middle East; 7.3% to South America; about 1% to Africa; and the remainder to the Caribbean and to Central America. Although a very small quantity of helium was imported by the

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United States in 1995, import tariffs on helium remained at the 3.7% rate for most favored nations established on January 1, 1987. The non-most-favored-nation tariff also remained unchanged at 25%. No changes in import tariffs are scheduled at this time.

World Review

World production capacity of helium, excluding the United States, was estimated to be 29 million cubic meters (1,045 million cubic feet). Most of the helium produced outside of the United States was extracted, in decending order of production, in Algeria, Poland, and Russia. The remainder was produced in small plants in China and India. (*See table 5.*)

Current Research and Technology

Technology that uses liquid helium to produce superconducting temperatures continues to be developed and utilized. Liquid helium continues to be used at Fermi National Accelerator Laboratory for Tevatron/Tevatron 1, which was the world's first superconducting particle accelerator. The liquid helium-cooled superconducting magnets used in this accelerator provide an intense and extremely steady magnetic field using only a fraction of the energy required by conventional electromagnets.

Argonne National Laboratory has developed magneto-hydrodynamic (MHD) propulsion systems for military and commercial use. This system has no moving parts, but uses magnetic fields and electricity to pump water through a tube. Researchers at Argonne used the world's largest liquid-helium-cooled superconducting dipole magnet to study this propulsion system; however, budget constraints have placed further MHD research on hold. One of the many benefits of this research has been the development of multidimensional MHD computer codes for analyzing flow development in and performance of MHD systems. Development of MHD technology could lead to a new generation of water transportation vessels that would travel more quickly, quietly, and efficiently than present ships.

Liquid helium use in magnetic resonance imaging (MRI) continues to increase as the medical profession develops new uses for this equipment. The MRI equipment is providing accurate diagnoses of medical problems where exploratory surgery was previously required. A medical application being developed uses MRI to determine, through blood analysis, if a patient has any form of cancer. Experiments using laser polarized helium gas or a noble gas dissolved in the bloodstream have improved medical imaging techniques and could lead to extensive advances in medical diagnostics (Clark, 1996). For example, the technique could be used to detect pulmonary embolisms before life-threatening situations occur. The method could also be used to determine the relationships between brain functions and the effect stimuli have on blood flow to the brain, or it could be used to image blood vessels to determine various heart conditions.

Lifting gas applications are increasing. The U.S. Navy and U.S. Air Force are investigating the use of airships to provide early warning systems to detect low-flying cruise missiles. The Drug Enforcement Administration has installed six tethered radar blimps along the southern border of the United States to detect drug smugglers. In addition, NASA is using helium-filled balloons to sample the atmosphere in Antarctica to determine what is depleting the ozone layer that protects the Earth from harmful ultraviolet radiation and to obtain information on early structures in the universe. In the commercial market, several companies in addition to Goodyear continue to use "blimps" for advertising.

The United States and Russia have joined research efforts to build a nuclear reactor that will destroy the plutonium stockpiles at the Tomsk-7 production facility in Russia and to produce electricity for the district. Helium coolant sent through the reactor core will pick up heat energy from the fuel rods and transfer that energy directly to a turbogenerator to generate electricity. If successful, the helium-cooled reactor could become an important alternative energy source in the future. Superconducting magnetic energy storage (SMES) also is being investigated to provide power for laser systems and electric power peak shaving in commercial applications. SMES allows the accumulation and storage of electrical energy over the long term (hours) when excess capacity is available and discharges it in minutes or as needed to provide for peak demands. Some small commercial units are already in service.

Other exciting research programs that use helium continue to push back the frontiers of science. For example, physicists have modeled the development of the universe using droplets of superfluid helium. By creating the conditions that cosmologists believe existed prior to the "big bang," scientists can theorize about the aftermath of that purported universe-creating explosion (Vergano, 1996).

Other evolving technologies that require the unique properties of helium are (1) metastable helium for energy storage, which involves raising helium electrons to an excited energy state and then stabilizing the atom there; (2) fiber-optic production, where an ultrapure inert atmosphere is required; (3) helium ion tumor treatment, where large inert particles are required; (4) liquid helium-cooled superconducting microswitches, called Josephson junctions, which are much faster than conventional semiconductors and use less power; (5) "aneutronic" nuclear fusion, where nuclear energy is produced by fusion of deuterium and helium-3, results in few or no neutrons; and (6) helium-hydrogen breathing mixtures that enable deep-sea divers to reach depths below 580 meters (1,700 feet).

Outlook

The total market for U.S.-produced helium decreased 1.5% from the 1995 sales level. Market growth rate continues to flatten at less than 1% for the 5-year period 1992-96. In addition, market growth rate for private industry helium is also flat at about 1% for the 5-year period 1992-96.

In 1996, private industry supplied about 93.6% of the

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domestic demand, while the Federal Government supplied the remaining 6.4%. Helium exports decreased 17.7% from those of 1995, accounting for 24.1% of U.S.-produced helium sales. Private industry supplied all of the U.S. helium exports. Strong growth in the Japanese helium market is expected to continue, and competition from foreign helium suppliers will provide increasing uncertainty for the global helium market. The sales outlook for helium remains slow in the Federal sector with cutbacks and elimination of programs that use and/or produce large volumes of helium. Helium sales in the private sector are expected to continue moderate-to-slow growth over the next 3 years. Use of high-temperature superconductor materials in electric motor windings and innovative applications of supercritical/cryogenic processing are expected to increase helium demand.

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TABLE 1
OWNERSHIP AND LOCATION OF HELIUM EXTRACTION PLANTS
IN THE UNITED STATES IN 1996

Category and owner or operator	Location	Product purity
Government-owned:		
Bureau of Land Management (BLM)	Masterson, TX	Grade-A helium. 1/
Private industry:		
Air Products Helium, Inc.	Hansford County, TX	Do.
Do.	Liberal, KS	Do.
BOC Gases Inc.	Otis, KS	Do.
CIG Co.	Keyes, OK	Grade-A helium. 1/
Do.	Lakin, KS	Crude helium. 2/
Exxon Co., U.S.A.	Shute Creek, WY	Grade-A helium. 1/
GPM	Hansford County, TX	Crude helium.
KN Energy, Inc.	Bushton, KS	Crude helium. 3/
Do.	Scott City, KS	Crude helium. 2/
Maxus Energy Corp.	Sunray, TX	Do.
Mesa, Inc.	Fain, TX	Do. 4/
Do.	Satanta, KS	Do.
National Helium Corp.	Liberal, KS	Do.
Nitrotec	Burlington, CO	Grade-A helium.
Do.	Cheyenne Wells, CO	Do.
Praxair, Inc.	Bushton, KS	Do. 1/
Do.	Ulysses, KS	Do. 1/
Trident NGL, Inc.	Do.	Crude helium.
Unocal	Moab, UT	Grade-A helium. 1/
Williams Field Services	Baker, OK	Crude helium.

1/ Including liquefaction.
2/ Lakin plant started production in August 1996.
3/ Output is piped to Ulysses, KS, for purification.
4/ Stopped production in May 1996.

TABLE 2
HELIUM RECOVERY IN THE UNITED STATES 1/ 2/

(Thousand cubic meters)

	1992	1993	1994	1995	1996
Crude helium:					
Bureau of Land Management (BLM) total storage	(9,360)	(8,850)	(7,200)	(7,600)	(7,230)
Private industry:					
Stored by BLM	25,300	29,600	38800	36100	36700
Withdrawn	(17,900)	(16,400)	-19500	-23200	-21200
Total private industry storage	7,400	13,200	19,300	12,900	15,500
Total crude helium	(1,960)	4,350	12,100	5,300	8,270
Stored private crude helium withdrawn from storage and purified by the BLM for redelivery to industry	(510)	(638)	(610)	(69)	--
Grade-A helium:					
BLM sold	8,630	7,930	6610	7210	6060
Private industry sold	85,800	87,600	93800	88900	88600
Total sold	94,400	95,500	100,000	96,100	94,700
Total stored	(2,470)	3,710	11,500	5,230	8,270
Grand total recovery	91,900	99,200	112,000	101,000	103,000

1/ Negative numbers are enclosed in parenthesis ( ) to denote net withdrawal from the BLM's underground storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
2/ Data rounded to three significant digits; may not add to totals shown.

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TABLE 3
TOTAL SALES OF GRADE-A HELIUM PRODUCED
IN THE UNITED STATES

(Million cubic meters)

	Volume		
Year	Domestic sales	Exports1/	Total sales
1992	63.7	30.7	94.4
1993	67.6	28.0	95.6
1994	75.4	25.0	100.4
1995	68.4	27.7	96.1
1996	71.9	22.8	94.7

1/ Source: Bureau of the Census.

TABLE 4
SUMMARY OF BUREAU OF LAND MANAGEMENT (BLM)
HELIUM CONSERVATION STORAGE SYSTEM OPERATIONS 1/ 2/

(Thousand cubic meters)

	1994	1995	1996
Helium in conservation storage system at beginning of period:			
Stored under BLM conservation program	885,000	878,000	870,000
Stored for private producers under contract	68,700	87,500	100,000
Total	954,000	965,000	970,000
Input to system:			
Net deliveries from BLM plants 3/	(7,200)	(7,600)	(7,230)
Stored for private producers under contract	38,800	36,100	36,700
Total	31,600	28,500	29,500
Redelivery of helium stored for private producers under contract 3/	(20,000)	(23,200)	(21,240)
Net addition to system 3/	11,500	5,300	8,260
Helium in conservation storage system at end of period:			
Stored under BLM conservation program	878,000	870,000	863,000
Stored for private producers under contract	87,500	100,000	116,000
Total	966,000	970,000	979,000

1/ Crude helium is injected into or withdrawn from the BLM's underground storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.
2/ Data rounded to three significant digits; may not add to totals shown.
3/ Numbers in parentheses indicate net withdrawl from storage.

TABLE 5
WORLD GRADE-A HELIUM PRODUCTION
CAPACITY, DECEMBER 31, 1996

(Million cubic meters)

	Capacity
United States 1/	114
Rest of world e/	29
Total e/	143

e/Estimated.
1/Includes capacity of plants on standby as well as operating plants.

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Figure 1

HELIUM RECOVERY IN THE UNITED STATES

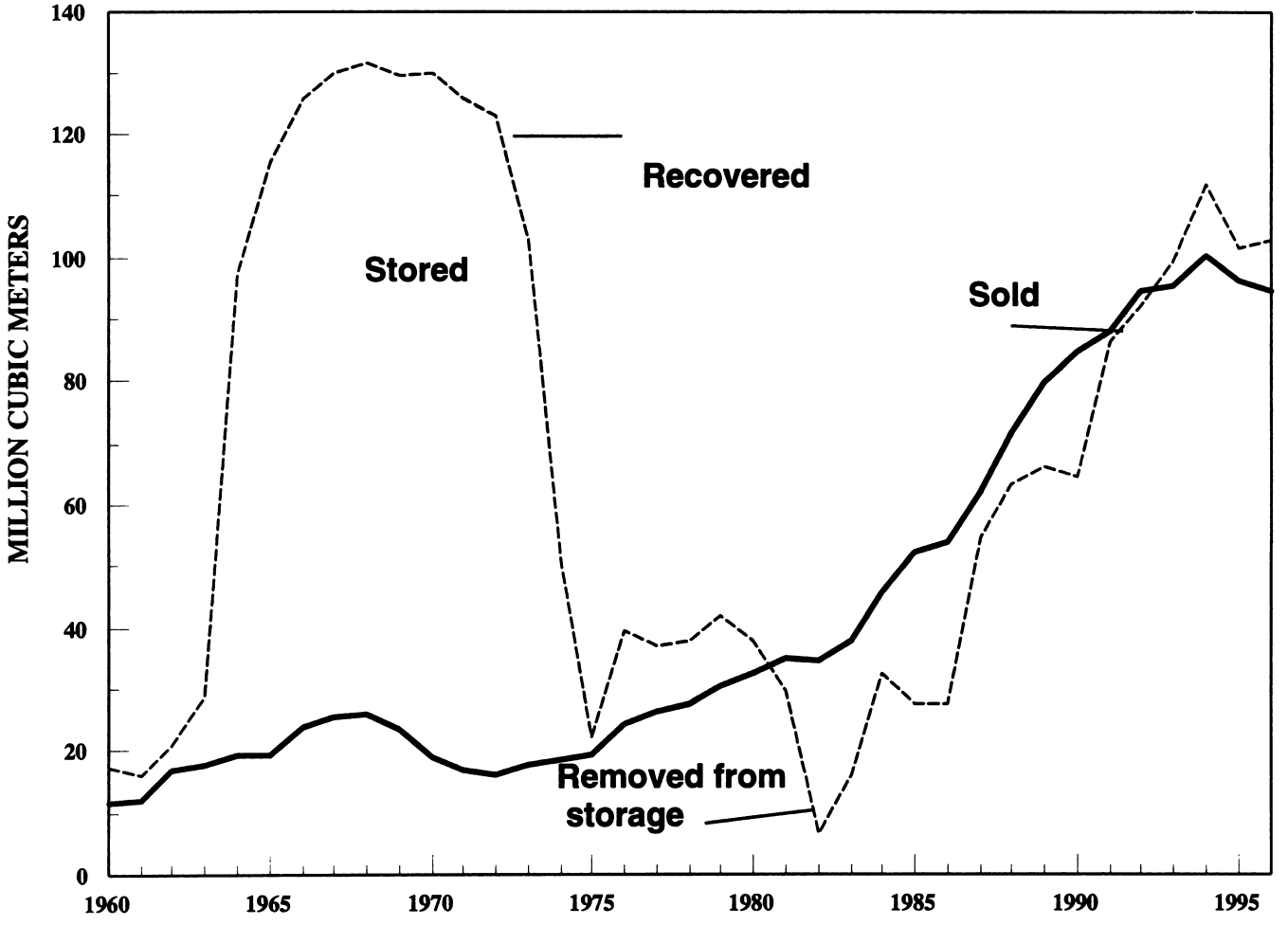

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FIGURE 2
MAJOR U.S. HELIUM-BEARING NATURAL GAS FIELDS

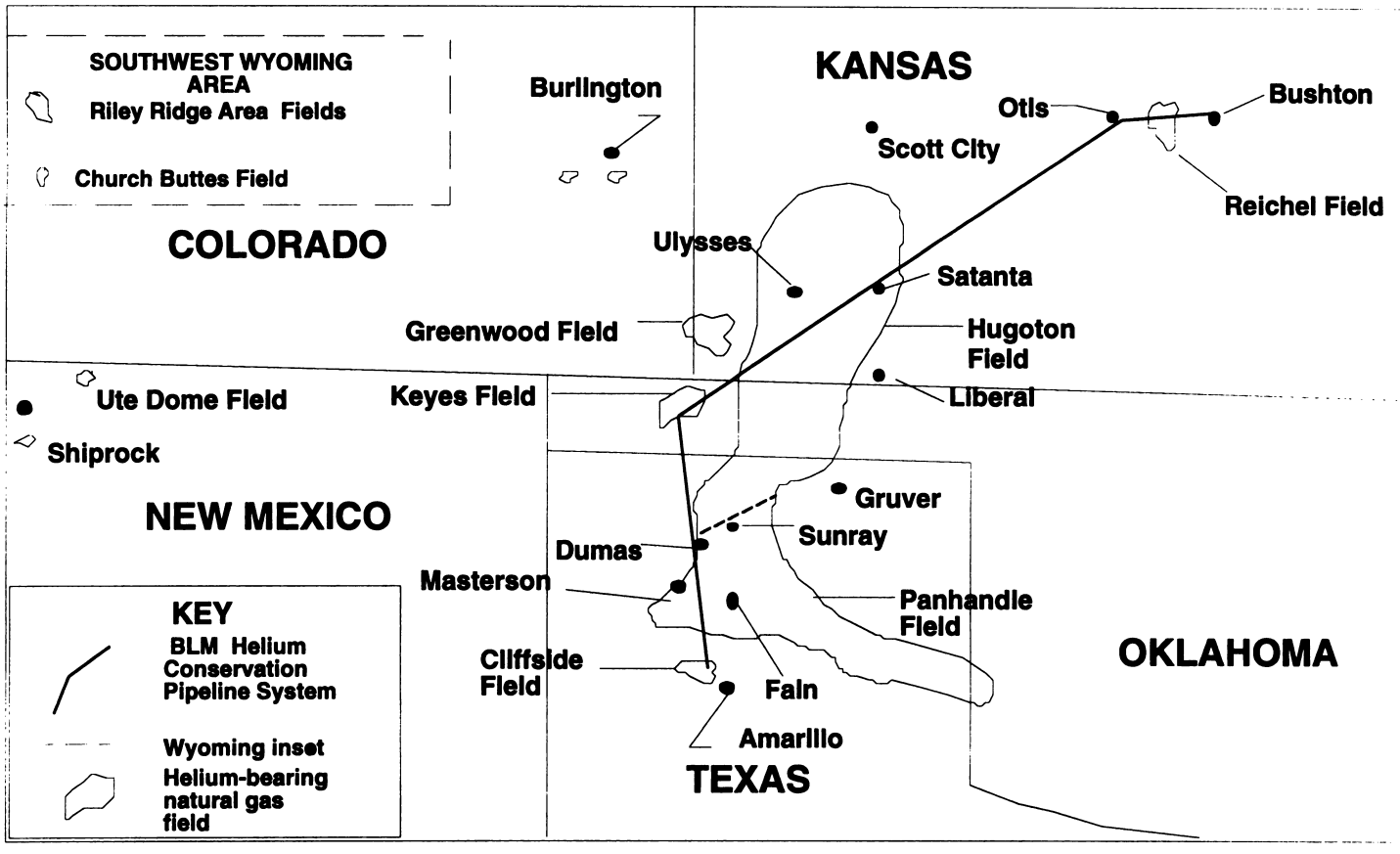

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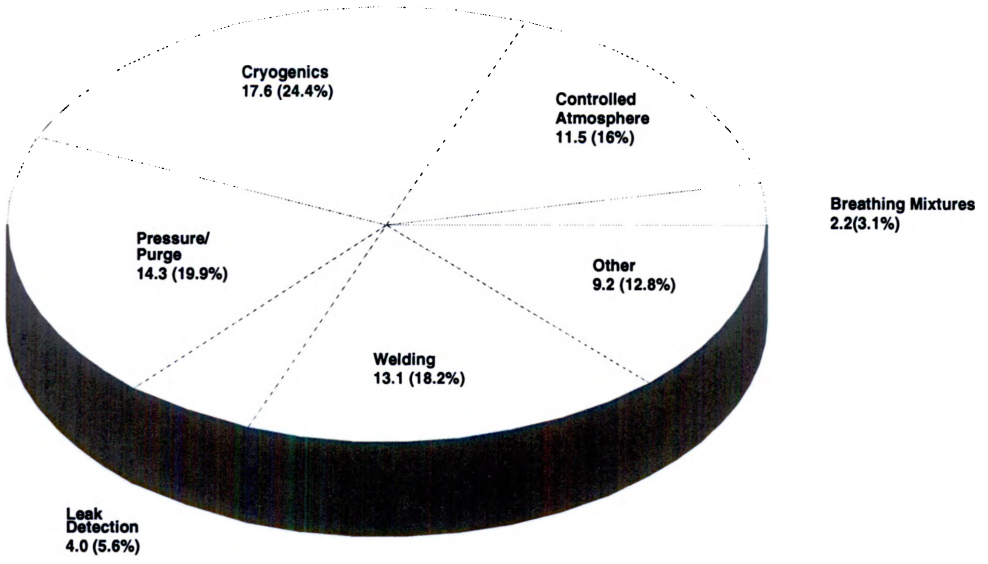
FIGURE 3
ESTIMATED HELIUM CONSUMPTION, BY END USE, IN THE UNITED STATES IN 1996
(Million cubic meters)



Estimated total helium used
(71.9 million cubic meters)

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INDIUM

By Robert D. Brown, Jr.

No indium was recovered from ores in the United States in 1996. Domestic indium production was confined almost entirely to the upgrading of imported metal. There was no known production at domestic mines. Two refiners, one each in New York and Rhode Island, were the major producers of indium metal and indium products in 1996. Several smaller firms also produced high-purity indium alloys, compounds, solders, sputtering targets, and related products.

Domestic consumption increased from about 43 metric tons to an estimated 45 tons. Estimated uses were about the same as those in 1995: coatings, 45%; solder and alloys, 35%; batteries and electronic uses, 15%; and research and other uses, 5%. The estimated value of primary metal consumed in the United States in 1996 was more than $17 million, at an average producer price of $11.50 per troy ounce.

Recycling became very significant for the first time in 1996 and was said by industry sources to have affected the market and prices. However, an estimate of the amounts of refined indium produced through recycling is not available.

World refinery production was estimated at 200 tons, a 16% decrease from the 1995 figure. There were eight major producing countries; the top four, Canada, France, Japan, and Russia, accounted for 75% of the total.

World consumption increased slightly in 1996. The large increase in demand in 1995 had caused a corresponding price increase that year. In 1996, although total consumption increased, with the reportedly dramatic increase in recycling, the demand for primary metal decreased. The producer price dropped from more than $16 per troy ounce in January to $6.53 per ounce at yearend.

World reserves are sufficient to meet anticipated demand for the next decade. Canada has greater resources of indium than any other country–about 27% of world reserves and 35% of the world reserve base. The corresponding amounts for the United States are 12% and 11%, respectively.

Legislation and Government Programs

The National Defense Stockpile inventory of indium on December 31, 1996, was unchanged from that of the previous year at 1,561 kilograms (50,187 troy ounces). The original stockpile goal for indium was 41,990 kilograms, but this was reduced to 7,740 kilograms in 1992. The first purchase of indium was made in 1992, with all the material supplied domestically. The inventory amount is the total of all purchases made for the stockpile. According to the Annual Materials Plan for fiscal year 1996, proposed by the Defense Logistics Agency, indium was to be eliminated from the stockpile, but congressional authority has allowed only 35,000 troy ounces to be offered for sale during any one fiscal year. No indium was sold from the stockpile in 1996.

Production

U.S. primary production consisted of upgrading lower grade and standard-grade indium (99.97% or 99.99%) into higher purity metal. Indium can be refined to purities up to 99.99999%. There was no known production at domestic mines; all the indium to be upgraded was imported. Domestic secondary production was mainly from new scrap and spent sputtering targets. The amount of indium produced from scrap increased from "small" to significant in 1996. Recycling became more economically viable as the price of indium increased nearly fourfold during 1995.

Consumption

Domestic consumption was estimated at about 45 tons, nearly a 5% increase from the 1995 level. Consumption in the diverse end uses increased proportionally. Indium was available in various forms, such as ingot, foil, powder, ribbon, shot, and wire.

Thin-film coatings on glass, which included indium oxide and indium-tin-oxide (ITO), constituted nearly one-half (45%) of total domestic indium use in 1996. The coatings, produced by sputtering the material onto a glass substrate, have been the largest area of research and growth for indium in the past several years.

There are two kinds of indium-containing coatings, electrically conductive and infrared reflecting. Electrically conductive coatings, the more commercially significant group, are used primarily in liquid crystal displays (LCD's) for watches, television screens, portable computer screens, video monitors, etc. They are also used to defog aircraft and locomotive windshields and to keep glass doors on commercial refrigerators and freezers frost free. Infrared reflecting coatings limit the transfer of radiant heat through windows, thus helping to make the wintertime heating and the summertime cooling of buildings more energy efficient.

About 35% of the indium consumed was used as an addition to combinations of bismuth, cadmium, lead, or tin to form low-melting-point alloys. These alloys are used in such applications as electrical fuses, fusible links, or as gripping material for the grinding of optical glass. Indium is used as a strengthening agent for lead solders and also as the base material for many low-melting-point solders. Indium-based solders have a number of advantages over ordinary solders: lower melting points, flexibility over a greater temperature range, and negligible

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leaching of gold components from electronic assemblies. Lead-free solders can be developed starting with indium-based alloys.

Indium can replace mercury in alkaline batteries, preventing the buildup of hydrogen gas in the sealed container. These batteries are available in popular small consumer sizes, and together with electronic uses, including semiconductors, accounted for 15% of the indium consumed domestically.

Prices

The domestic producer price as reported by *Platt's Metals Week* for 99.97%- to 99.99%-pure indium declined steadily throughout 1996. Prices for higher grades of metal were not published. The course of the price during the year was nearly the reverse of that in 1995, except that the decline in 1996 was more gradual than the increase in 1995. The producer price fell from $16.25 per troy ounce at the beginning of the year to $6.53 per ounce at the end. This drop of nearly 60% was caused by an excess supply of metal, the result of much greater activity in the recycling of indium materials, which, in turn, was spurred on by high prices in 1995. The price dipped below $15 per ounce during the first quarter, reached $11.50 by midyear, finished the third quarter at $9.33, and in the fourth quarter, dropped to $6.53. During 1995, the price never went down; during 1996, it never went up. The major causes for the price collapse were greater (and cost competitive) recycling rates and—on a world basis—the increase in exports from China. As little as 35% of the indium in ITO used for LCD's for flat screen television sets reaches the product, owing to inefficiencies in the sputtering process. The rest is available as scrap, which can be recycled (Fineberg, 1996a). Industry sources said that the cost of recycling indium is only about $6 per troy ounce (Fineberg, 1996b). Some of the scrap was recycled under tolling arrangements between consumers and producers (Metal Bulletin, 1996d).

Foreign Trade

Immediately after a record-high year for U.S. indium imports, a 21% increase for 1995 over that of 1994, 1996 brought a 61% decrease. Imports fell from 85.2 tons to 33.2 tons. This decrease apparently was made up for by increased recycling. With such a big decrease, comparative trade patterns with individual countries can appear skewed, but Canada retained its position as the top supplier by a wide margin. Next, in order of importance, were Russia, France, Belgium, and Peru. The top three countries provided 73% of U.S. imports, and the top five provided 88%. China fell from second to sixth rank in exports to the United States. Data for exports from the United States were unavailable.

World Review

Canada.—The reopening of the Mount Pleasant Mine in New Brunswick would firm up Canada's standing as an indium producer. The mine, now owned by the Adex Mining Corp., based in Toronto, was previously operated by Billiton Metals as a producer of tungsten and molybdenum. Proven reserves reportedly include 9 million tons grading 1 ounce of indium per ton and 5.1 million tons grading 2.6 ounces of indium per ton. Reserves also include bismuth, copper, molybdenum, tin, tungsten, and zinc. Both the completion of final feasibility studies and a decision to proceed were expected by yearend (Metal Bulletin, 1996a).

Adex has obtained the partnership of the Malaysian Smelting Corp. (MSC), which is interested in the Mount Pleasant project as a long-term source of tin concentrate. MSC will invest $28 million in the project—$2 million for the final feasibility study and the balance for reopening the mine. The mine is expected to show a profit in 4 years with values from tin (55%), indium (30%), zinc (6%), copper (5.5%), and bismuth (3.5%). The biooxidation pilot plant studies for indium recovery were on schedule, and the mineralization zone appeared larger than previously estimated (Adex Mining Corp., 1996).

China.—As with a number of other "minor" metals, China holds at least one of the keys to the future of the indium market. With a general long-term backdrop of increasing demand, the world market has been in fairly close balance of supply and demand, with a few tons shortfall or oversupply not unusual or unexpected. China's relatively new ability to supply more than 25 tons per year to the world market from a combination of production and stockpiles is significant. China can produce at least 28 tons per year, while its current consumption is only 2 tons (Metal Bulletin, 1996b). Indium is produced in Shanghai, and in Shenyang and Huludao in Liaoning Province, and in Zhuzhou in Hunan Province.

Japan.—Japan, the world's largest consumer of indium, also experienced a large drop in imports as well as a decrease in primary production. These decreases in imports and production despite strong consumption are explained partly by increased processing of ITO scrap, which had previously been stockpiled. It had been unprofitable to process this material at the low (before 1995) market prices for indium. Since 1995, more than one-half of Japanese indium consumption has been used for ITO applications (Roskill's Letter from Japan, 1996). Further, it was reported that Japanese consumers may have been stockpiling indium in 1995—albeit unintentionally perhaps—as LCD production unexpectedly outstripped demand. Consumption then declined in 1996 as stocks were used. Also, the rate of growth of devices using LCD's may have declined. Such softening in a market that was expected to maintain previous high growth rates resulted in lower demand and lower prices.

Current Research and Technology

The most significant technological development for 1996 was the large increase in recycling of indium-containing materials, mostly used sputtering targets and scrap from their manufacture. Details on the technology itself are not available, although it has been reported that one domestic processor uses a coprecipitaion process to reclaim ITO and other indium products (Roskill, 1996).

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Researchers from many academic and industrial laboratories followed various approaches to developing lead-free solders for electronic applications. The studies included indium-base systems in general as well as the specific systems tin-indium, tin-zinc-indium, tin-silver-indium (-antimony), and tin-bismuth-indium. Research done by the industrial laboratories included potential applications in communications and transportation (Journal of Metals, 1996).

Outlook

Consumption of indium is expected to increase through the next decade, especially for LCD's, high-definition television, semiconductor materials, batteries, and low-temperature solders for military and electronic applications. Demand for other uses, such as replacement nuclear control rods and fusible alloys, should remain steady. Surges in demand or breaks in supply have caused increases in price in the past. If indium prices rise, research and development into substitutes for ITO for LCD's, and on recycling, will be stimulated. Zinc-tin-oxide could possibly be used as a substitute, but currently its properties are not as good as those of ITO. If the price of indium is sufficiently high, recycling will be economically attractive and will tend to limit upward movements in price as long as there is a supply of appropriate scrap. World reserves, together with increases in production capacity, through increased yields in primary recovery and improvements in recycling technology (Metal Bulletin, 1996c), are expected to be sufficient to meet the demand for indium through the next decade.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDIUM, BY CLASS AND COUNTRY 1/

Class and country	1995 Quantity (kilograms)	1995 Value (thousands)	1996 Quantity (kilograms)	1996 Value (thousands)
Unwrought and waste and scrap:				
Belgium	4,030	$1,120	2,600	$748
Cameroon	--	--	112	29
Canada	32,800	12,700	13,000	3,780
China	14,500	6,390	1,700	768
Finland	--	--	21	10
France	4,770	2,020	5,420	2,360
Germany	2,670	537	202	24
Hong Kong	1,450	555	194	80
Israel	--	--	170	36
Japan	3,620	1,370	679	265
Lithuania	75	18	--	--
Netherlands	--	--	276	93
Peru	1,630	705	2,480	757
Russia	14,300	5,420	5,900	2,930
Spain	1,450	465	--	--
Switzerland	2,000	884	--	--
United Kingdom	1,810	809	486	214
Total	85,200	32,900	33,200	12,100

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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IODINE

By Phyllis A. Lyday

Three producers of crude iodine supplied about 32% of domestic demand; the remainder was imported. Because some exports and imports are in product categories rather than crude products, net imports are not clearly distinguished. The major world producer, Japan, produced iodine from brines associated with gas production. The second largest producer, Chile, produced iodine as a coproduct of sodium nitrate.

Legislation and Government Programs

The Strategic and Critical Materials Stock Piling Act, as amended, gives the U.S. Department of Defense authority to maintain a stockpile of strategic and critical materials to supply the military, industry, and essential civilian needs of the United States for national defense. By 1968, 3.7 million kilograms (kg) (8.1 million pounds) had been acquired. In 1992, Public Law 102-484 reduced the stockpile goal to zero, and Congress authorized the sale of excess material. Proposed sales of iodine for fiscal year 1996 were 204,117 kg (450,000 pounds). No stockpile iodine was sold or bartered during 1996 and the excess iodine remained at 2,362,235 kg (5,207,831 pounds).

The U.S. Environmental Protection Agency (EPA) was seeking revision of more than a dozen types of polymers and resins, according to a notice published in the November 25, 1996, Federal Register. (Iodine is used as a stabilizer in tall oil resins (TOR).) The new proposal would affect control requirements for storage vessels, continuous process vents, equipment leaks, heat exchange systems, and wastewater that were included in two final rules promulgated by EPA in September. One rule regulates emissions of hazardous air pollutants from the manufacture of nine types of polymers and resins used in elastomers. A second regulation covers the manufacture of seven categories of polymers and resins used in thermoplastics (Chemical Marketing Reporter, 1996d).

Production

Domestic production data for iodine are derived from a voluntary survey of U.S. operations by the U.S. Geological Survey (USGS). Of the three operations to which a survey request was sent, all responded, representing an estimated 100% of the total production. (*See tables 1 and 6.*)

In 1987, IOCHEM Corp. began producing iodine by the blowing-out process at a plant 1.2 kilometers (km) east of Vici, Dewey County, OK,. IOCHEM is a privately held joint venture between Tomen America Inc. and a private family. The majority of production was shipped to Schering AG, Germany, under a long-term contract. IOCHEM reported to have nine production wells and four injection wells with a total production capacity of 1,400 tons per year at Vici.

North American Brine Chemicals began operating a miniplant at Dover in Kingfisher County, OK, in 1983. Two plants are at an oilfield injection disposal site that obtains brines from about 50 wells in the Oswego Formation. Iodine concentrations were as much as 1,200 parts per million (ppm). In 1993 the company closed a plant that began operating in 1991 because of the low market prices for iodine.

Woodward Iodine Corp., which began production in 1977 was purchased by Asahi Glass Co. of Japan in 1984. Woodward operated the plant in Woodward County, OK that produced iodine from 22 brine production wells using the blowing-out process and injected waste through 10 injection wells.

Consumption

Estimated end uses by percentage for iodine in 1996 were estimated from a USGS canvass of consumers as follows: Sanitation (39%); pharmaceutical (24%); heat stabilizers (13%); catalyst (9%); animal feed (7%); and other (8%). Other smaller uses included inks and colorants, photographic chemicals, laboratory reagents, production of batteries, high-purity metals, motor fuels, and lubricants. (*See table 2.*)

Iodine deficiency is the world's leading cause of mental defects in the form of severe retardation, deafness, mutism, and partial paralysis, as well as more subtle problems, such as clumsiness, lethargy, and reduced learning capacity. Iodine is an essential part of a thyroid hormone that contributes to fetal brain development and metabolism after birth. A worldwide effort is underway to eliminate iodine-deficiency disorders by fortifying the world's salt supply.

TOR is used as a "paper size," and in ink resins and tackifying resins for adhesives. The main competition for TOR was hydrocarbon resins made from byproducts of ethylene production. Three U.S. companies use iodine to stabilize TOR. Arizona Chemical, the speciality products division of International Paper, developed a new resin that helps adhesives and sealant manufacturers achieve better processing and reduce the amount of tackifiers found in their formulations (Chemical Marketing Reporter, 1996c).

Berlex Laboratories, Wayne, NJ, with more than $500 million in 1995 sales, is a leader in magnetic resonance imaging (MRI) contrast media. Berlex is a good indicator of the value of newer generation contrast media products that use iodine (Chemical Manufacturing Reporter, 1996a).

Hoechst Aktiengesellschaft, Germany, announced that the

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name "Celanese" is to become the official name of Hoechst's global basic chemicals subsidiary, headquartered in Dallas, TX. Celanese is a consumer of iodine as a heat stabilizer (Layman, 1997).

Ecolab is the leading global developer and marketer of cleaning, sanitizing, and maintenance products and services for the hospital, institutional, and industrial markets (Iodine is a major product in these products.) (The PointCast Network, unpub. Data accessed February 26, 1997, on the World Wide Web at URL http://pointcast.com.)

Mallinckrodt Medical Imaging Division of Mallinckrodt Inc., St. Louis, MO, produces substances to enhance X-ray imaging by using iodated contrast media. The company supplies several X-ray contrast agents, including Conray, Hexabrix, and Optiray. Imaging media still consist largely of X-ray products, and the contrast media are based chiefly on iodide and, to a lesser extent, barium (Chemical Manufacturing Reporter, 1996b). These products make Mallinckrodt a leader in X-ray contrast media. Optiray, an ioversol, is the only new generation X-ray contrast media discovered, developed, and marketed in the United States; ioversol is non-ionic and has an organically bound iodine content of 47.2%. The Mallinckrodt Nuclear Medicine Division has facilities to produce and ship radioactive ingredients in the United States and the Netherlands. Sodium Iodide^{131} Diagnostic Capsules and Sodium Iodide^{131} are two of the more than two dozen nuclear products in which Mallinckrodt is a world leader. Mallinckrodt Catalysts & Chemical Additives produces potassium iodide to help produce new plastics that have specific attributes, such as strength or flexibility (Mallinckrodt Inc., 1997).

Nycomed, the North American unit of Nycomed Corp., an imaging and pharmaceutical company, Oslo, Norway, produces an iohexol, Omnipaque, which is a nonionic water-soluble radiographic contrast medium with an iodine content of 46.36%. Nycomed also markets a gadodiamide, Omniscan, which is a nonionic contrast agent for use in MRI of the central nervous system. Introduced in 1993, Nycomed says Omniscan is the second most often used MRI product in the U.S. market. In 1996, the Food and Drug Administration approved three new indications for Omniscan-body, high-dose central nervous system, and pediatric (Chemical Manufacturing Reporter, 1996b).

Homeowners of private wells must disinfect their own water supply to make it bacteriologically safe to drink. A new method of disinfection involves adding iodine to water. Iodine is proven effective in a relatively short contact time. A common method of feeding iodine is the diffusion feed technique in which a portion of the water is diverted though a vessel containing iodine crystals. Water diverted through this small bypass dissolves a portion of the iodine and returns to the main flow, adding a dilute but calculated amount of iodine. High concentrations of iodine are, however, necessary to be effective, organic matter inhibits its efficiency. Iodine can also produce a taste found objectional by many and is expensive (Water Quality Association, 1996).

Prices

Crude iodine prices quoted in trade journals increased in 1996. The average declared c.i.f. value for imported crude iodine was $12.90 per kg. The average declared c.i.f. value for imported crude iodine from Japan was $12.18 per kg. The average declared c.i.f. value for iodine imported from Chile was $13.63 per kg. The average producer price was $11.47 per kg. Quoted yearend U.S. prices for iodine and its primary compounds are shown in table 3.

Foreign Trade

The General Agreement on Tariffs and Trade (GATT) was signed into law in December 1994 and took effect January 1, 1995. GATT lowers chemical tariffs by an average of 30%. Chemicals, including bromine, are the Nation's largest export commodity, as more than 10 cents out of every export dollar is a product of the chemical industry. The agreement's intellectual property provisions include greater patent protection for products developed by American firms. GATT changes patent enforcement from 17 years from the date of issue to 20 years from the date of application. Patents issued on applications filed before June 8, 1995, will be enforceable for either 17 years from the issue date or 20 years from the filing date, whichever is longer.

The U.S. Government adopted the Harmonized Commodity Description and Coding System (Harmonized System) as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. The Harmonized System, as proposed, includes resublimed and crude iodine under the same code, and a free duty rate. Values that differ significantly could be a result of items being placed in the wrong category. (*See tables 4 and 5.*)

The ministers of the World Trade Organization met in December and approved the permanent establishment of the Committee on Trade and the Environment (CTE). The U.S. chemical industry will be an active participant because there are several major environmental issues affecting trade that it would like to see resolved. The Chemical Manufacturers Association (CMA), as a major representative of the U.S. chemical industry, finds eco-labeling to be one area on which it and its European counterparts cannot agree. Ecolabels list specific environmental standards on packaging, recycling, and even production processes before the product can be imported into Europe. In a policy paper, CMA stated, "The proliferation of different types of environmental labeling systems...contributes to the creation of nontariff barriers." Problems arise when countries try to unilaterally use trade measures to achieve environmental goals. The issue of flexibility in achieving international environmental objectives will continue at future CTE meetings (Hanson, 1997).

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World Review

Chile.—Chile was the second leading producer of iodine, and new projects continued to be announced to increase production. Boron Chemical International Ltd., Vancouver, Canada, announced the commercial development of the Aguas Blancas project in northern Chile for the production of iodine, sodium sulfate, and potassium nitrate. The caliche ore body is 95 km southeast of Antofagasta. By using a cut-off of 200 parts per million (ppm) iodine, the proven and probable reserves are 29.5 million metric tons; most of the caliche averages 683 ppm iodine. Overburden is less than 1 meter. Processing of the ore involves crushing, leaching with fresh water, thickening, filtration, and iodine precipitation. Construction began during the first quarter of 1996. By 1998, the planned design would produce 1,000 tons of iodine, 150,000 tons of sodium sulfate, and 70,000 tons of potassium nitrate per year (Industrial Minerals, 1996).

Compania de Salitre Y Yodo de Chile (Cosayach) part of Inverraz S.A., mines iodine and nitrates from caliche reserves in the first and second region of Chile. Reserves consist of more than 90,000 hectares, which correlate to 300,000 tons of iodine and 50 million tons of sodium nitrate. The Cala-Cala plant, begun in 1991, has a capacity of 648-tons-per-year. The Negreiros plant, begun in 1995, has a capacity of 1080-tons-per-year. The Soledad plant, to begin in 1997, will have a capacity of 1080-tons-per-year. Total capacity in 1996 was 2808-tons-per-year. The processing uses bulldozers and truck to a leaching area where ore is deposited 4 to 4.5 meters high on a base of poly vinyl chloride waterproof liner. A sprinkling system provides water to dissolve the salts found in the ore. The solutions are captured and sent to the iodine plant for recovery where iodide is reduced with sulfur dioxide to iodide. The precipitated is refined and then washed to produce 99.7% pure iodine. The solution is concentrated by a two stage crystallizer and solar evaporation to achieve a nitrate rich solution, which produces sodium or potassium nitrate. The design capacity is 200,000-tons-per-year of nitrates. Nitrate production was expected to reach more than 400,000 tons by the end of 1999 (Sarah Hall, Tamaya Chemical Corp., written commun. 1997).

KAP Resources Ltd., Vancouver, Canada, announced that its Chilean subsidiary, Cia Minera Yolanda SA, was to begin production at the $80 million facility that is expected to be completed in 1997. Gulf Fertilizers and Chemicals has signed a 3 year contract to market the iodine (Green Markets, 1997).

Sociedad Quimica y Minera de Chile (SQM; formerly known as SOQUIMICH) produced 99.5% iodine as a byproduct of nitrate production. SQM Iodine S.A. continued production at its satellite plants, which produced about 1,000-tons-per-year of crude iodine. One satellite plant, owned by Cimin, a subsidiary of SQM Iodo (a subsidiary of SQM) is located about 100 km from the main mines. In August Cimin's Pinto plant came on line at 1,000-tons-per-year. This plant complements a 500-tons-per-year unit that opened in the first quarter. Cimin brought online 1,500 metric tons of added capacity during 1996. All the iodine production was in Chile's Region II. New construction for 1997 will be in Region I, the furthest north of Chile's 13 regions. SQM planned a 1,500-ton-per-year plant to be on stream by June 1997. The new plant is in the same area as Minera Mapocho, a medium-sized producer acquired by SQM in 1996, that added 400 tons of iodine capacity. Overall, SQM has planned to invest $30 million in iodine expansion that will take its total production capacity to more than 8,000 tons in 1997 (Chemical Marketing Reporter, 1996b, 1997b).

Chile is the second largest producer of crude iodine in the world and the U.S. depends on imports for more than half of supply, good trade relations with Chile is of national concern. Chile was invited to join the North American trade bloc, which links the United States, Canada, and Mexico, at the first Summit of the Americas in December 1994. Chile has, however, declined to go forward until the U.S. Congress passes fast-track authority. With fast track, lawmakers would vote either for or against any trade agreement with no opportunity for amendments. Trade between the United States and Chile passed the $6 billion mark during 1996. The United States imports Chilean salmon, wine, and fresh fruit, and U.S. companies are investing, for the most part in mining (PointCast Network, 1997b).

Europe.—The International Council for Control of Iodine Disorders was founded in 1986 to eliminate iodine deficiency disorder (IDD) in all countries by 2000. There are more than 400 members in some 70 countries and regions. The Council was admitted into official relations with the World Health Organization in 1994 (http://tron.is.s.u.tokyo.ac.jp/who/programmes/ina/ngo/ngo-48.htm).

Arizona Chemical will double its European capacity of high-viscosity hard resins for offset ink. Resins from Arizona's European tall oil refineries will be supplemented with gum rosin purchases sufficient to sustain the new capacity. The expansion is the second in Europe since acquiring DSM Andeno B.V.'s ink resins business in late 1995. Arizona Chemical produces ink resins in Niort, France, Sandarne, Sweden, and Valkeakoski, Finland (Chemical Marketing Reporter, 1997a).

Japan.—Japan was the world's leading producer of iodine. Six companies operated 17 plants with a total production capacity of 9 million kg per year. Production of iodine was from underground brines associated with natural gas. Two plants that closed in midyear 1994 reopened with total output reported to be 1,000 tons per year (Chemical Marketing Reporter, 1997b). On April 1, 1996, the Japanese Government repealed Japan's Provisional Measures Law on the "Importation of Specific Kinds of Petroleum Refined Products" (Oil & Gas Journal, 1996). As a result, Japan's oil companies must restructure operations to develop new strategies to compete in a more open market. The effects on the production of natural gas shall not be known until energy becomes deregulated and more abundant at less cost.

Turkmenistan.—The Nebitdag plant is located in Vyshka, 26 km south west of the Nebitdag City in Balkan velayat. The source of bromine and iodine is underground brines of the Nebitdag-Monjoukley deposit. The plant reported production capacities of 255 tons per year of iodine and 3,200 tons of

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ferrous bromide per year as well as 1,300 tons of bromine derivatives and 100 tons of sodium hypochlorite per year. It was commissioned in 1969 and has 33 employees.

The Cheleken plant is located 10 km north in Cheleken City in Balkan velayat. The source of iodine and bromine is underground brines of the Cheleken deposit. The plant's reported production capacities are 335 tons of iodine and 6,400 tons of ferrous bromide per year. In addition, the plant produces 60 tons of potassium iodide, 45 tons of potassium iodate, 60 tons of other derivatives, and 100 tons per year of sodium hypochlorite per year. The plant was commissioned in 1932 and has 548 employees (Saparmurat Noureyer, 1996). (See table 6.)

Current Research and Technology

In 1995, when Chemical & Engineering News magazine investigated chemical companies on the World Wide Web (WWW), only a few had web sites. These sites had a small amount of public relations information, such as what the company produces, corporate headquarters locations, press releases, and electronic mail connections. Now some companies are planning automated shipment tracking, computerized problem solving, and two-way customer service offerings. Many companies put their WWW pages up quickly and plan to redesign them in the future. Trade associations are using the WWW to communicate with members through newsletters and mentor networks. Other associations list trade shows and position papers with links to related documents, such as the Federal Register. Some companies, however, have completely disconnected their computer system from the WWW to maintain the security of their company data (Kirschner, 1996).

Methyl iodide was tested by the University of California at Riverside and found to be an effective fumigant for controlling four species of fungi, one species of nematode, and seven species of weeds. Based on the results of 15 laboratory and field trials, methyl iodide was found to be more effective than methyl bromide as a fumigant (Orr, Sims, and Grech, 1996). Methyl iodide has an ozone depletion potential of less than 0.016 and appears to be a replacement for methyl bromide in most uses. Methyl iodide is about five times more expensive, however, but could utilize the same equipment as methyl bromide (European Chemical News, 1996).

Electrophilic nitroarenes can be converted to nitroanilines with an iodine derivative. This chemistry may be a way to demilitarize dimethylhydrazine rocket fuel (Chemical & Engineering News, 1996).

Lobster harvesters have been removing the eggs of lobsters by exposing the crustaceans to chlorine. To subvert this subterfuge, lobster inspectors put the small appendages of the lobster in potassium iodide solution. In the presence of chlorine, the solution turns yellow. The test was developed by the Woods Hole (Massachusetts) Marine Biological Laboratory and the State Lobster Hatchery and Research Station, Vineyard Haven, MA (Chemical & Engineering News, 1997a).

In 1979, humans were exposed to radioactive iodine at the Three Mile Island (TMI), PA, nuclear powerplant. A new study by Steven Wing, associate professor of epidemiology at the University of North Carolina, Chapel Hill, and colleagues conclude that cancer and leukemia rates in residents downwind of the reactor range from 2 to 10 times higher than those in residents living upwind. Radioactive gas was released from TMI after a partial meltdown of the plant's radioactive core (Chemical & Engineering News, 1997b).

Outlook

During the past decade, iodine production capacity in the United States and Chile has doubled, thus ensuring an adequate world supply. Future overall growth in traditional uses is projected to grow by as much as 2% per year (Chemical Product Synopsis, 1996). Uses for iodine in specialty chemicals have remained stable. Recent developments in digital images using computers can produce electronic prints and overhead transparencies without the need for wet processing. By using a digital camera or scanning the film and converting to digital, the images are produced and stored on hard drives, disks, tape, or optical storage.

Digital imaging is used for recording most sporting events, game shows, and some situation comedies for television broadcast. From 75% to 85% of all televised programs seen during prime time are recorded on 35-mm motion picture film and then transferred to video tape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film because the main reason for this is better image quality. A frame of 35-mm color negative film contains about 6.6 million pixels, or about 15 times that of the best current high-definition television system and 4 times that of the digital systems now in development. Most popular home video rentals have been box office movie hits which were filmed and then transferred to video. Future use of iodine in films and processing could be limited to specialty imaging in the next decade as digital imagery technology improves and cost of acquisition of equipment become more affordable.

New uses of fluoroiodocarbon as halogen replacements may cause an increased demand for iodine. More tests need to be completed on the iodated fluorocarbons before they are acceptable, but preliminary tests are promising. Supplemental programs designed to alleviate IDD in China and India are consuming large amount of iodine. X-ray contrast media, containing up to 60% iodine, continues to have between 4% and 5% annual growth. In Mexico and Chile, the use of individual water purification units that use iodine are a new application. Purification applications could become significant consumers of iodine (Chemical Marketing Reporter, 1997b).

Automotive International reports that the director of engineering material at Du Pont Automotive foresees a 72% increase in the use of nylon during the next eight years; iodine is used as a stabilizer in nylon. This would result in about 7 kg of nylon in the average car in the United States by 2005. Air

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intake manifolds provide the greatest growth area, although nylon is also making inroads into other components, such as cylinder-head covers (FT Information Online Ltd., 1997).

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TABLE 1
SALIENT IODINE STATISTICS 1/

(Thousand kilograms unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production	2,000	1,940	1,630	1,220	1,270
Imports for domestic consumption 2/ 3/	3,750	3,620	4,360	3,950	4,810
Exports 2/ 3/	1,810	1,220	1,200	1,220	2,380
Consumption:					
Reported 4/	3,400	3,550	3,690	3,680	3,910
Apparent 5/	3,930	4,330	4,780	3,540	3,700
Price, imports, average c.i.f. value 6/, dollars per kilogram	$9.03	$7.98	$8.02	$10.32	$12.82
World: Production	16,500	15,700	14,200 r/	12,900 r/	13,100 e/

e/ Estimated. r/ Revised.

1/ Except for prices, data are rounded to three significant digits; may not add to totals shown.

2/ Bureau of the Census.

3/ Only the crude iodine "content" of the potassium iodide as declared by tables 4 and 5 is incorporated in data or calculations for this table.

4/ Reported by voluntary response to the U. S. Geological Survey from a survey of domestic establishments.

5/ Defined as "Imports minus exports plus adjustments for Government and domestic industry stock changes."

6/ Bureau of the Census. "Cost, insurance, and freight" (c.i.f.).

TABLE 2
DOMESTIC CONSUMPTION OF CRUDE IODINE, BY PRODUCT 1/

(Thousand kilograms)

	1995		1996	
Product	Number of plants	Quantity	Number of plants	Quantity
Inorganic compounds:				
Resublimed iodine	8	198	6	336
Potassium iodide	8	955	7	893
Sodium iodide	4	87	6	380
Ammonium iodide	2	W	1	W
Calcium iodate	1	W	2	W
Cuprous iodide	3	29	3	21
Hydriodic acid	3	27	3	255
Potassium iodate	3	73	5	82
Other inorganic compounds	10	613	8	412
Total	XX 2/	1,830	XX 2/	2,500
Organic compounds:				
Ethylenediamine dihydroiodide	3	608	5	480
Methyl and/or ethyl iodide	1	W	3	20
Povidone-Iodine (Idophors)	3	829	2	W
Other organic compounds	3	410	5	905
Total	XX 2/	1,850	XX 2/	1,410
Grand total:				
Reported consumption 3/	XX 2/	3,680	XX 2/	3,910
Apparent consumption 4/	XX	3,540	XX	3,700

XX Not applicable. W Withheld to avoid disclosing company proprietary data; included with "Other inorganic/organic compounds", respectively.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Nonadditive because some plants produce more than one product concurrently.

3/ Reported by voluntary response to the U. S. Geological Survey in a survey of domestic establishments.

4/ Calculated by using domestic consumption plus imports minus exports.

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TABLE 3
YEAREND 1996 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

Elemental iodine/ compounds	Value (dollars)	
	Per kilogram 1/	Per pound 1/
Calcium iodate, FCC drums, f.o.b. works	16.42	7.45
Calcium iodide, 50-kilogram drums, f.o.b. works	30.00	13.61
Iodine, crude, drums	15.00-16.00	6.81-7.26
Iodine, U.S.P., drums	15.01	6.80
Potassium iodide, U.S.P., drums, 5,000-pound lots, delivered	26.48	12.01
Sodium iodide, U.S.P., crystals, 5,000-pound lots, drums, freight-equalized	36.38	16.50

1/ Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Market Reporter. Current Prices of Chemicals and Related Materials; V. 250, No. 27, Dec. 30, 1996, p. 20-27.

TABLE 4
U.S. CRUDE IODINE AND POTASSIUM IODIDE IMPORTS FOR DOMESTIC CONSUMPTION, BY COUNTRY OF ORIGIN 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1995		1996	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude:				
Canada	12	146	9	75
Chile	1,890	18,300	2,340	32,000
Germany	--	--	4	93
Japan	1,860	18,800	2,250	27,400
Russia	39	354	54	560
Total	3,800	37,500	4,660	60,100
Iodide, potassium: 4/				
Brazil	(5/)	3	--	--
Canada	105	927	182	1,920
Chile	24	400	11	175
India	20	276	5	64
Italy	2	10	--	--
Japan	--	--	1	9
Total	151	1,610	199	2,230
Grand total	3,950	39,100	4,860	62,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import information for "Crude iodine" and "Potassium iodide" are reported by HTS numbers 2801.20.0000 and 2827.60.2000, respectively.
3/ Declared c.i.f. valuation.
4/ Gross potassium iodide contains 76% crude iodine.
5/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE, BY COUNTRY OF DESTINATION 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1995		1996	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude/resublimed:				
Brazil	24	190	--	--
Canada	49	816	50	948
Egypt	--	--	2	34
France	75	723	35	524
Germany	561	4,650	370	4,540
Ghana	2	38	--	--
India	17	199	10	143

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE,
BY COUNTRY OF DESTINATION 1/

(Thousand kilograms and thousand dollars)

Material type and country of origin 2/	1995		1996	
	Quantity	Value 3/	Quantity	Value 3/
Iodine, crude/resublimed--Continued:				
Israel	12	43	4	45
Italy	6	100	36	469
Mexico	388	3,280	1,670	9,190
Netherlands	--	--	90	1,070
Turkey	--	--	16	22
United Kingdom	13	99	15	191
Other 4/	23	294	15	390
Total	1,170	10,400	2,320	17,600
Iodide, potassium: 5/				
Australia	(6/)	5	(6/)	2
Belgium	5	93	11	155
Canada	18	364	38	713
Mexico	4	48	7	82
Netherlands	--	--	10	138
Thailand	1	24	(6/)	10
Turkey	15	238	15	246
Other 7/	2	64	6	147
Total	45	836	88	1,490
Grand total	1,220	13,000	2,400	19,100

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Export information for "Iodine: Crude/resublimed" and "potassium iodide" are reported by HTS numbers "2801.20.0000" and "2827.60.2000," respectively.

3/ Declared "Free alongside ship" (f.a.s.) valuation.

4/ Includes Argentina and Belgium (1996); Colombia; Denmark (1996); El Salvador (1995); Honduras, Hong Kong and Indonesia (1996); Japan; the Republic of Korea (1995); Malaysia (1995); Panama; Philippines (1996); South Africa and Sweden (1995); Switzerland (1996); Venezuela.

5/ Gross potassium iodide contains 76% crude iodine.

6/ Less than 1/2 unit.

7/ Includes Argentina (1995); Brazil, Denmark, France, Guatemala, India, Indonesia, and Jamaica (1996); Malaysia; Peru (1996); Philippines, Switzerland (1996); Taiwan; Venezuela (1996).

Source: Bureau of the Census.

TABLE 6
CRUDE IODINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand kilograms)

Country	1992	1993	1994	1995	1996 e/
Azerbaijan e/	600	500	400	350	300
Chile e/ 3/	5,839 4/	5,550	5,600	5,000	5,000
China e/	500	500	500	500	500
Indonesia	35 e/	14	89	77	75
Japan	6,764	6,489	5,592	5,492 r/	5,500
Russia e/	200	180	160	160	150
Turkmenistan e/	600	500	251	137 r/ 5/	255
United States	2,000	1,940	1,630	1,220	1,270 5/
Total	16,500	15,700	14,200	12,900 r/	13,100

e/ Estimated. r/ Revised.

1/World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 10, 1997.

3/ Includes iodine production reported by Servicio Nacional de Geologia y Mineria (SERNAGEOMIN) as follows in thousand kilograms: 1992--1,028; 1993--1,121; 1994--1,268; and 1995-96--not available.

4/ Includes iodine production reported by the nitrate industry (Industria Salitrera).

5/ Reported figure.

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IRON AND STEEL

By Michael Fenton

Iron and steel are the basic metals of an industrial society and are vital to the United States for its national security and economic well-being. Although acceptable substitutes are available for many uses, they are not practical on a large scale at this time because of the cost and lack of availability of alternative materials.

Data regarding U.S. production of iron and steel and shipments of steel mill products were reported by the American Institute of Iron and Steel (AISI). These data can be regarded as representing 100% of the raw steel producers in the United States. World production of iron and steel is reported by the International Institute of Iron and Steel (IISI) and by foreign government agencies. Consistent with international usage and Federal Government policy, the U.S. Geological Survey is reporting all data on iron and steel in metric units, unless otherwise noted.

Environment

The term "brownfield" generally applies to abandoned, idled, or underused industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental polution. Many brownfield sites are found throughout the United States; some are abandoned steel plants, which continue to deteriorate in urban centers. These industrial properties, sometimes thousands of acres in size, are not easily sold for redevelopment because of continuing seller liability after environmental cleanup. The steel industry continues to seek liability relief for sellers of brownfield sites. When a site is cleaned up, the owner or responsible party must obtain relief from all forms of environmental liability before the property can be sold for redevelopment. The U.S. Senate Steel Caucus addressed this issue, which was the subject of a number of bills introduced in the 104th Congress.

Production

Production of raw steel in the United States increased only slightly to 95.5 million metric tons from 95.2 million tons in 1995. AISI estimated raw steel production capability to be 105.3 million tons, up from 102 million tons in 1995. Production represented 90.7% of estimated capability, compared with 93.3% from that of 1995.

Integrated steel producers smelt iron ores to liquid iron in blast furnaces and use basic oxygen furnaces to refine this iron with some scrap to produce raw liquid steel. The basic oxygen process was used to make 54.8 million tons of steel. The use of this process declined somewhat from 59.6% of total steel production in 1995 to 57.4%. The integrated steel industry in the United States consisted of 15 companies operating ironmaking and steelmaking facilities at 22 locations. Several of these companies also operated nonintegrated plants and/or other steelmaking facilities at the same locations.

Minimills and specialty mills are nonintegrated steel producers. Minimills use modern technology to produce a limited product line with maximum efficiency. These plants always incorporate electric arc furnaces (EAF) to melt low-cost raw materials (usually scrap), continuous casting machines, and a hot rolling mill that is often closely coupled to the casting operation. Specialty mills include producers of stainless, alloy-electrical, and tool steel; high-temperature alloys; forged ingots; and other low-volume steel products. The EAF steelmaking process was used to produce 40.7 million tons of steel, an increase of 6.0% over that of 1995, and accounted for 42.6% of total steelmaking. Overall, the nonintegrated sector of the industry consisted of more than 65 companies having more than 90 steelmaking plants.

Raw liquid steel is mostly cast into semifinished products in continuous casting machines. Only 6.7% of U.S. production was cast in ingot form and subsequently rolled into semifinished forms; this represents a decrease from 8.8% in 1995. Continuous casting production was 89.0 million tons, or 93.3% of total steel production, compared with 86.7 million tons and 91.1% in 1995.

Consumption

"Steel mill products" are produced at a steel mill, either by forging or rolling, in forms normally delivered for fabrication or use. Some companies purchase semifinished steel mill products from other steel companies and use them to produce steel mill products. To avoid double counting steel mill product shipments under these circumstances, steel mills identify any shipments of steel mill products to other companies that are reporters of steel mill product shipments. The accumulated shipments of all companies less the shipments to other reporting companies are identified as "net" shipments.

The 5-year trend of steadily increasing net shipments of steel products to satisfy domestic demand continued; in fact, the amount of products shipped was the highest in 22 years. Shipments of steel mill products by U.S. companies increased 3.5%, to 91.5 million tons. Export shipments by AISI reporting companies reversed an upward trend that had started the previous year by falling dramatically from 4.03 million tons (revised) in 1995 to 2.11 million tons. Shipments to domestic customers rose 6% during 1996. The oil and gas, mining,

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quarrying, and lumbering industries and makers of construction products continued rising trends of 22% and 4%, respectively. Steel service centers and distributors and manufacturers of appliances and of industrial and agricultural machinery, equipment, and tools increased 14%, 8%, and 3%, respectively. Manufacturers of automobiles, the largest single end-use market, and of containers, packaging, and shipping materials remained essentially unchanged.

High demand for steel put a strain on production facilities and may have been responsible, in part, for blast furnace outages at several major integrated producers, including U.S. Steel Group, National Steel Corp., Weirton Steel Corp., and Rouge Steel Co. The repair costs, in addition to lower average selling prices, contributed to reduced operating income and per-ton operating profits. Operating income declined because steel prices were depressed by cheap imports. Nevertheless, the industry as a whole remained profitable but below 1995 levels.

Prices

The Bureau of Labor Statistics Producer Price Index for steel mill products was down by 3.7%, from 120.1 in 1995 to 115.7 (1982 base = 100). The index declined during the first quarter, rose during the second and third quarters to the January level, and remained essentially constant for the remainder of the year.

Foreign Trade

Exports of steel mill products declined dramatically to 4.6 million tons from 6.4 million tons, the highest level since 1940, in 1995. Canada again received the largest amount of U.S. exported steel, 2.2 million tons, essentially the same as that of 1995. Mexico was again in second place, receiving an increase of over 0.2 million tons, to nearly 1.0 million tons.

Imports of steel mill products increased by 19% to 26.5 million tons from 22.1 million tons in 1995. Brazil, Canada, the European Union (EU), Japan, the Republic of Korea, Mexico, and Russia were major sources for steel mill product imports. After the dramatic increase in 1994 of imported steel mill products from Russia and Ukraine, when more than 2 million tons was imported, imports from these countries declined about 6% in 1995. In 1996, combined imports increased 7.5% above the record level of 1994.

The striking increase in imports of steel mill products over that of the previous year appeared to be influenced by domestic and foreign conditions. Foreign steel markets were not absorbing available steel. The U.S. market became more attractive to foreign producers as prices rose moderately, partly as a result of plant furnace shutdowns and resulting shortages of semifinished steel. Surging imports prompted complaints by some domestic steelmakers of unfair trade practices. During November, Geneva Steel Co. and Gulf States Steel Inc. filed antidumping petitions with the U.S. Department of Commerce and the International Trade Commission (ITC) against imports of cut-to-length carbon plate from China, Russia, Ukraine, and South Africa (Steel Industry Update, 1997). Geneva Steel also filed a lawsuit against importers Thyssen Steel Group and Ranger Steel Supply Corp. for selling underpriced plate imports from these countries. Citing forced layoffs, declining orders, and the inability to raise capital, the two companies were supported by Bethlehem Steel Corp. and six steel service centers. Domestic producers had been complaining that prices of imported plate were as much as $100 less than those of U.S. plate. Although these petitions were specifically concerned with carbon plate, 21 of the 36 product categories tracked by the AISI showed increases in imports. Stainless steel producers blamed imports for their pricing and profit problems and threatened trade law suits. Imports of stainless steel wire products were increasing at an alarming rate, and the U.S. Stainless Wire Action Committee was formed to study the problem. In December, the ITC ruled that plate imports had caused material injury to domestic producers (Sacco, 1997).

The rising trend of imported semifinished steel for rolling, believed to have been imported by U.S. steel companies to supplement steelmaking capacity, ended temporarily in 1995 after 3 years as imports of mostly ingots, blooms, billets, and slabs declined 34% from the 1994 high of about 7.2 million tons to 4.7 million tons. During 1996, imports resumed their upward trend, increasing to 6.8 million tons, 45% over that of 1995.

The increase in imports of semifinished steel by steel companies must be taken into consideration in evaluating total consumption of steel mill products in the United States and the share of the market represented by imported steel. To avoid counting the imported semifinished steel and the products produced from it, the amount of semifinished steel consumed by companies that also produce raw steel must be subtracted from domestic consumption. For 1996, this amount was estimated to have been 5 million tons. For 1993, 1994, and 1995, the amount of such imports was estimated to be 2.5 million, 5 million, and 2.5 million tons, respectively, and prior to 1993, the annual amount was less than 0.5 million tons. Taking the imported semifinished steel into consideration, the share of the U.S. steel market represented by imported steel was an estimated 24%, compared with 22% in 1994.

Regarding the reporting of imports and exports, "fabricated steel products" are produced from steel mill products, but do not include products that incorporate steel products with other materials. Examples of fabricated steel products are fabricated structural steel and steel fasteners. "Other iron and steel products" refers to products that are not produced from steel mill products. Examples of other iron and steel products include iron or steel castings and direct-reduced iron (DRI).

World Review

World production of pig iron totaled about 528 million tons, slightly less than that of 1995. In Asia, China continued to be the leading producer of pig iron in the world, producing more than 105 million tons, essentially unchanged from the 1995 total. Japan and the United States followed with 75 million and 49 million tons, respectively. The Republic of Korea's production continued to increase by 3.0%. Russia and Ukraine

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were the only major pig iron producers in the former Soviet Union (FSU). Production in Russia decreased to that of 1994 after an increase of 10%, to nearly 40 million tons, reversing a 3-year decline, in 1995. Production in Ukraine decreased by 9%, to 18 million tons, during that same period. In North America, the only major producer of pig iron was the United States, where production was about equal to that of 1995. In South America, the only major pig iron producer was Brazil, producing about 25 million tons per year from 1994 through 1996. Germany was the top producer in the EU with 30 million tons. Italy increased production by nearly 3%.

DRI production was almost 32 million tons, an increase of nearly 4% since 1995 and 55% since 1992. The leading technology was the Midrex process, followed by the HYL III and the HYL I processes. Demand for charge materials and the growth of thin slab casting caused increased interest in DRI by steel producers. Direct reduction of iron ore proved to be a cost-effective way for developing countries, especially those with an abundance of natural gas, to encourage economic growth. The leading producer continued to be Venezuela, followed by India, Mexico, and Iran. World capacity for DRI production was estimated to be nearly 38 million tons per year. Additional capacity of 13 million tons was under construction in Australia, China, Egypt, India, the Republic of Korea, Mexico, Peru, Russia, South Africa, Saudi Arabia, the United States, and Venezuela. After the addition of several DRI plants, India's capacity reached more than 5 million tons per year. Five plants remained under construction, having a combined capacity of more than 0.5 million tons per year.

World production of crude steel was more than 758 million tons, only a small increase from the 754 million tons produced during 1995. As in previous years, production varied widely among major regions of the world. Asian countries produced 38% of the world's steel; the EU, 20%; and North America, 16%. During 1996, China became the world's leading steel producer, reaching 100 million tons, a gain of 4.8% over that of 1995. The leading producers behind China, in declining order, were Japan, the United States, Russia, and Germany. These five countries accounted for about one-half of world production. The combined steel production of the 10 steel-producing states in the FSU was less than 80 million tons; Russia and Ukraine remained the top producers. Production in Russia declined by 4% after reversing a declining 3-year trend with a 5% increase in 1995. Ukrainian production was stable at its 1995 level. In the former Soviet satellite states of Eastern Europe, steel production declined to nearly 31 million tons, a decrease of nearly 10%, compared to that with 1995.

Outlook

The global economy as a whole has been growing and is expected to continue to do so, attributed, in part, to reduced interest and inflation rates and the increasing sizes of the economies of developing countries. The steel sector will participate in world economic growth on the basis of new and replacement infrastructure needs; increasing usage of steel in the automotive, construction, and beverage container industries; and increasing demand for durable goods. Growth of Asian steel demand and local steel industries to meet this demand, especially in China, will be greater than in the relatively mature industrial countries of North America and Europe. Growth of demand in North America may be modest at best, while demand in Europe should return to modest growth after a recent period of decline caused by public spending reductions and tax increases.

Factors providing the greatest impetus for growth in the world steel industry are industrial privatization, focus on free-market development, and the trend to EAF steelmaking. Privatization of the steel industries of Mexico, Brazil, and Italy are notable examples of changes in state control, but the most significant changes are underway in China, Eastern Europe, and the FSU. The demand for steel in China, which had been partially fueling the free-market economic boom during the early 1990's, is expected to continue at record growth rates, at least in the short term. Free trade and new investment will be encouraged, at least in North America, by such agreements as the General Agreement on Tariffs and Trade and the North American Free Trade Agreement. If global steel supply exceeds demand, then protectionist trade measures, especially in Europe, may be taken.

The deterioration of the U.S. highways and bridges was brought to the attention of the 104th Congress by AISI and the Steel Manufacturers Association. According to Federal Government statistics, 234,500 miles of U.S. road were listed as poor or mediocre, and one-third of all bridges were rated as being structurally deficient or functionally obsolete. Infrastructure rebuilding will require more than $900 billion during the next 20 years. According to an American Automobile Association study (Christianson, 1996), $72 billion is needed to improve the road system during the next 5 years, and $53 billion is needed to maintain current conditions. In response, Congress allocated more than $20 billion for construction of roads, bridges, and tunnels, a 1.6% increase over that of 1996.

As the prices of lumber continue to rise and the quality of the lumber falls, steel producers will be actively seeking a larger share in the residential construction market. Galvanized steel is more fireproof and impervious to pests, more durable, stronger, more precisely machined, and easier to assemble than wood. The goal of steel producers is to increase their share of the Nation's homes framed with steel from 1% to 25% by 2000.

The automobile industry will continue to be a significant user of steels and cast iron. Because the U.S. Government, among others, has recognized the need to decrease vehicle weight as a way of decreasing air pollution, manufacturers probably will be forced to replace iron and steel with lightweight materials, such as aluminum and plastic. During the past 6 years, however, the unit content of steel in domestically produced family vehicles has increased, and the demand for light trucks with a greater steel content has been increasing. To protect and increase its share in the automotive market, 32 steel companies from 15 countries are designing steel car bodies in the UltraLight Steel

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Auto Body project. The steel industry also is working with vehicle manufacturers to find cost-effective ways to ensure maximum use of iron and steel.

U.S. minimills began as small, simple, inexpensive, lightly manned producers of carbon steel, mostly long products, that used local sources of scrap for feedstock for local distribution. In contrast, integrated steel plants were large, complex, capital and labor intensive, multiproduct enterprises that used raw materials from diverse and distant sources to make a wide range of products for domestic and foreign markets. The distinction between these two types of steelmakers will become increasingly blurred as the integrated companies reduce costs of labor, capital, and operations and the minimills become more capital intensive; increase costs; invest in sources of iron units, such as DRI, as alternatives to scrap; and produce a wider range of high-quality flat and long products. U.S. steelmakers will continue to improve product quality, to reduce costs, and to focus on improving export performance, given an increase in domestic supply and declining domestic demand over the short term. Opportunities are abundant for those in the steel industry that are able to adapt to new world conditions.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT IRON AND STEEL STATISTICS 1/

(Thousand metric tons)

	1992	1993	1994	1995	1996
United States:					
Pig iron:					
Production 2/	47,400	48,200	49,400	50,900	49,400
Exports 3/	33	27	56	56	60
Imports for consumption 3/	497	828	2,500	2,360	2,660
Direct-reduced iron:					
Production 4/	390	440	480	460	450
Exports 3/	9	17	18	5	3
Imports for consumption 3/	542	1,090	1,170	1,190	1,050
Raw steel production: 5/					
Carbon steel	74,800	78,800	81,200	84,000 r/	84,900
Stainless steel	1,810	1,770	1,840	2,050 r/	1,870
All other alloy steel	7,710	8,220	8,180	9,080	8,710
Total	84,300	88,800	91,200	95,200	95,500
Capability utilization, percent	82.2	89.1	93.0	93.3	90.7
Steel mill products:					
Net shipments 2/	74,600	80,800	86,300	88,400	91,500
Exports 5/	3,890	3,600	3,470	6,420	4,560
Imports 5/	15,500	17,700	27,300	22,100	26,500
Producer price index for steel mill products 6/ (1982=100.0)	106.4	108.2	113.4	120.1	115.7
World production: 7/					
Pig iron	503,000	507,000 r/	516,000 r/	533,000 r/	529,000 e/
Direct-reduced iron 4/	20,500	23,600	27,300 r/	30,800 r/	32,900 e/
Raw steel	724,000	730,000	730,000	755,000 r/	758,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices; may not add to totals shown.

2/ Data from American Iron and Steel Institute (AISI).

3/ Data from Bureau of the Census.

4/ Data from Midrex Direct Reduction Corporation.

5/ Raw steel is defined by AISI as steel in the first solid state after melting, suitable for rolling.

6/ Data from Bureau of Labor Statistics.

7/ Data from U.S. Geological Survey and International Iron and Steel Institute.

TABLE 2
MATERIALS CONSUMED IN BLAST FURNACES AND PIG IRON PRODUCED 1/

(Thousand metric tons)

Material	1995	1996
Iron oxides: 2/		
Ores	1,200	862
Pellets	67,600	64,900
Sinter 3/	12,400	11,600
Total	81,200	77,400
Scrap 4/	1,700	1,700
Coke 2/	22,300	20,700
Pig iron produced	50,900	51,200

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ American Iron and Steel Institute.

3/ Includes sintered ore and pellet fines, dust, mill scale, and other revert iron-bearing materials; also some nodules.

4/ Mainly briquetted turnings and borings, shredded scrap, etc.; scrap produced at blast furnaces and remelt not included.

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TABLE 3
DISTRIBUTION OF SHIPMENTS OF STEEL MILL PRODUCTS, BY STEEL TYPE, PRODUCT, AND MARKET 1/

	Thousand metric tons		Percent	
	1995	1996	1995	1996
Shipments by steel type:				
Carbon steel	82,100	84,400	92.8	92.2
Alloy steel	4,640	5,400	5.3	5.9
Stainless steel	1,720	1,730	1.9	1.9
Total shipments by steel type	88,400	91,500	100.0	100.0
Steel mill products:				
Ingots, blooms, billets and slabs	2,380	2,310	2.69	2.29
Wire rods	4,450	4,620	5.03	5.05
Structural shapes-heavy	5,180	5,170	5.86	5.65
Steel piling	515	399	.58	.44
Plates-cut lengths	4,930	5,010	5.57	5.48
Plates-in coils	3,280	2,860	3.70	3.12
Rails	483	544	.55	.59
Railroad accessories	89	109	.10	.12
Bars-hot-rolled	6,260	6,350	7.08	6.94
Bars-light-shaped	2,120	2,110	2.39	2.30
Bars-reinforcing	4,580	5,230	5.18	5.71
Bars-cold finished	1,620	1,530	1.83	1.67
Tool steel	66	61	.07	.07
Pipe and tubing-standard pipe	1,270	1,400	1.44	1.53
Pipe and tubing-oil country goods	1,350	1,630	1.53	1.78
Pipe and tubing-line pipe	1,070	1,080	1.21	1.18
Pipe and tubing-mechanical tubing	964	954	1.09	1.04
Pipe and tubing-pressure tubing	37	35	.04	.04
Pipe and tubing-stainless	24	25	.03	.03
Pipe and tubing-structural	174	180	.20	.20
Pipe for piling	43	43	.05	.05
Wire	593	592	.67	.65
Tin mill products-blackplate	310	296	.35	.32
Tin mill products-tinplate	2,400	2,490	2.71	2.72
Tin mill products-tin-free steel	796	840	.90	.92
Tin mill products-tin coated sheets	75	97	.08	.11
Sheets-hot-rolled	15,400	15,800	17.40	17.31
Sheets-cold-rolled	11,200	12,800	12.70	13.97
Sheets and strip-hot dip galvanized	10,300	10,400	11.60	11.36
Sheets and strip-electrogalvanized	2,940	3,350	3.32	3.66
Sheets and strip-other metallic coated	1,570	1,600	1.78	1.75
Sheets and strip-electrical	386	417	.44	.46
Strip-hot rolled	734	520	.83	.57
Strip-cold rolled	897	871	1.01	.95
Total-steel mill products	88,400	91,500	100.00	100.00
Shipments by markets:				
Service centers and distributors	21,500	24,600	24.40	26.89
Construction	13,500	14,100	15.30	15.41
Automotive	13,300	13,300	15.00	14.54
Machinery	6,530	6,880	7.39	7.52
Containers	3,750	3,720	4.25	4.07
All others	29,800	28,900	33.70	31.59
Total shipments by market	88,400	91,500	100.00	100.00

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 4
U.S. IMPORTS AND EXPORTS OF STEEL MILL PRODUCTS, BY COUNTRY 1/

(Thousand metric tons)

Country	1995		1996	
	Imports	Exports	Imports	Exports
Argentina	112	9	99	6
Australia	--	18	--	13
Brazil	1,930	19	2,560	18
Canada	4,140	2,230	4,450	2,170
China	369	215	434	39
European Union	5,400	828	7,990	320
Finland	94	1	196	1
Japan	2,240	247	1,820	63
Korea, Republic of	1,270	475	1,250	169
Mexico	2,060	738	2,640	958
Russia	1,360	--	1,510	--
South Africa	(2/)	--	(2/)	21
Sweden	188	2	263	3
Taiwan	118	431	88	133
Trinidad and Tobago	(2/)	--	(2/)	--
Turkey	425	--	289	--
Ukraine	585	--	729	--
Venezuela	--	61	--	59
Other	1,850	1,150	2,140	590
Total	22,100	6,420	26,500	4,560

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Unable to distinguish country breakdown. Included with "Other."

Source: American Iron and Steel Institute.

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TABLE 5
U.S. EXPORTS OF IRON AND STEEL PRODUCTS 1/

(Thousand metric tons)

	1995	1996
Steel mill products:		
Ingots, blooms, billets, and slabs	418	282
Wire rods	63	95
Structural shapes-heavy	431	319
Steel piling	33	31
Plates-cut lengths	221	180
Plates-in coils	480	212
Rails-standard	7	37
Rails-other	7	11
Railroad accessories	15	19
Bars-hot-rolled	269	319
Bars-light-shaped	88	105
Bars-concrete reinforcing	114	97
Bars-cold-finished	83	86
Tool steel	6	8
Pipe and tubing-standard pipe	64	70
Pipe and tubing-oil country goods	249	273
Pipe and tubing-line pipe	244	203
Pipe and tubing-mechanical tubing	11	11
Pipe and tubing-stainless	21	21
Pipe and tubing-nonclassified	224	227
Pipe and tubing-structural	35	41
Pipe for piling	4	4
Wire	115	96
Tin mill products-blackplate	14	5
Tin mill products-tinplate	290	323
Tin mill products-tin-free steel	51	54
Sheets-hot-rolled	1,710	433
Sheets-cold-rolled	551	462
Sheets and strip-hot-dip galvanized	149	94
Sheets and strip-electrogalvanized	94	137
Sheets and strip-other metallic coated	104	98
Sheets and strip-electrical	34	36
Strip-hot-rolled	74	42
Strip-cold-rolled	149	137
Total steel mill products	6,420	4,560
Fabricated steel products:		
Structural shapes-fabricated	230	203
Rails-used	23	17
Railroad products	47	38
Wire rope	6	11
Wire-stranded products	28	21
Wire-other products	15	81
Springs	51	61
Nails and staples	20	23
Fasteners	376	447
Chains and parts	22	23
Grinding balls	32	31
Pipe and tube fittings	23	28
Other 2/	42	48
Total fabricated steel products	914	1,030
Total all steel products	7,340	5,600
Cast iron and steel products:		
Cast steel pipe fittings	120	107
Cast iron pipe and fittings	23	24
Cast steel rolls	16	15
Cast grinding balls	16	28
Granules-shot and grit	31	25
Other castings	44	41
Total cast iron and steel products	250	240

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes shapes-cold formed, sashes and frames, fence and sign post, and architectural and ornamental work.

Source: American Iron and Steel Institute.

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TABLE 6
U.S. IMPORTS OF MAJOR IRON AND STEEL PRODUCTS 1/

(Thousand metric tons)

	1995	1996
Steel mill products:		
Ingots, blooms, billets and slabs	4,720	6,830
Wire rods	1,690	1,770
Structural shapes-heavy	606	933
Steel piling	69	62
Plates-cut lengths	1,320	1,710
Plates-in coils	789	1,200
Rails and railroad accessories	192	183
Bars-hot-rolled	1,040	1,070
Bars-light-shaped	144	143
Bars-reinforcing	483	528
Bars-cold-finished	258	236
Tool steel	116	124
Pipe and tubing-standard pipe	685	686
Pipe and tubing-oil country goods	164	210
Pipe and tubing-line pipe	449	554
Pipe and tubing-mechanical tubing	277	298
Pipe and tubing-pressure tubing	40	44
Pipe and tubing-stainless	48	51
Pipe and tubing-nonclassified	11	12
Pipe and tubing-structural	401	349
Pipe for piling	10	7
Wire	550	507
Tin mill products-blackplate	130	120
Tin mill products-tinplate	272	250
Tin mill products-tin-free steel	152	154
Sheets-hot-rolled	2,910	3,760
Sheets-cold-rolled	2,820	2,680
Sheets and strip-hot-dip galvanized	1,140	1,420
Sheets and strip-electrogalvanized	193	144
Sheets and strip-other metallic coated	119	107
Sheets and strip-electrical	91	99
Strip-hot-rolled	66	55
Strip-cold-rolled	181	165
Total steel mill products	22,100	26,500
Fabricated steel products:		
Structural shapes-fabricated	189	234
Rails-used	186	248
Railroad products	97	53
Wire rope	92	82
Wire-stranded products	126	136
Springs	296	288
Nails and staples	328	367
Fasteners	890	837
Chains and parts	90	90
Pipe and tube fittings	81	106
Other	220	237
Total fabricated steel products	2,600	2,680
Total all steel products	24,700	29,100
Cast iron and steel products:		
Cast steel pipe fittings	36	36
Cast iron pipe and fittings	39	45
Other products	244	263
Total cast products	319	344

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 7
U.S. IMPORTS OF STAINLESS STEEL 1/

(Metric tons)

Product	1995	1996
Semifinished	122,000	102,000
Plate	107,000	127,000
Sheet and strip	306,000	344,000
Bars and shapes	85,400	91,000
Wire and wire rods	72,000	75,300
Pipe and tube	48,000	51,300
Total	741,000	791,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

TABLE 8
U.S. SHIPMENTS OF IRON AND STEEL CASTINGS 1/

(Thousand metric tons)

	1995	1996
Ductile iron castings	3,900 r/	3,830
Gray iron castings	5,680 r/	5,610
Malleable iron castings	266	238
Steel castings	1,050 r/	1,110
Steel investment castings	84 r/	81
Total	11,000 r/	10,900

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 9
COAL AND COKE AT COKE PLANTS 1/ 2/

(Thousand metric tons)

	1995	1996
Coal: Consumption	30,000	28,800
Coke: 3/		
Production	21,500	20,900
Exports	680	1,020
Imports	1,650	1,010
Consumption, apparent	22,200	20,900

1/ Data are rounded to three significant digits.

2/ Includes furnace and merchant coke plants.

3/ Coke production and consumption do not include breeze.

Source: Energy Information Administration, Quarterly Coal Report (DOE/EIA-0121).

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TABLE 10
PIG IRON 1/ AND DIRECT-REDUCED IRON: 2/ WORLD PRODUCTION, BY COUNTRY 3/ 4/

(Thousand metric tons)

Country 5/	1992	1993	1994	1995	1996 e/
Albania e/	10	10	10	10	10
Algeria	1,100	925	919	940 r/	850
Argentina:					
Pig iron	966	984	998	1,050 e/	1,000
Direct-reduced iron	1,027 r/	1,156	1,266	1,360 r/	1,420 6/
Australia	6,384	6,714	7,466	7,476 r/	7,381 6/
Austria	3,074	3,390	3,362	3,838 r/	3,800
Belgium	8,533	8,178	8,974 r/	9,199 r/	9,000
Bosnia and Herzegovina e/	150 6/	100	100	100	100
Brazil:					
Pig iron	23,152	23,982	25,177	25,090	25,100
Direct-reduced iron	290 r/	250	220	300	340 6/
Bulgaria	837	998	1,442	1,607 r/	1,513 6/
Burma:					
Pig iron	1	2	1	2 e/	2
Direct-reduced iron	10	20	10	20	20
Canada:					
Pig iron	8,621	8,633	8,150	8,464	8,500
Direct-reduced iron	639	740	770	1,010	1,417 6/
Chile	873	917	883	850	850
China	75,890	87,390	97,409	105,300 r/	105,300
Colombia	308	238	245 r/	282 r/	288 6/
Croatia e/	40	40	--	--	--
Czech Republic 7/	XX	4,668	5,287	5,289	5,200
Czechoslovakia 8/	8,039	XX	XX	XX	XX
Egypt:					
Pig iron	1,062	1,326	1,148	1,062 r/	1,050
Direct-reduced iron	826 r/	837 r/	774 r/	860	830 6/
Finland	2,452	2,535	2,597	2,242 r/	2,400
France	13,051 r/	12,679 r/	13,293	13,154 r/	13,000
Georgia	274	88	--	-- e/	--
Germany:					
Pig iron	27,399 r/	26,970	29,923	29,828 r/	30,000
Direct-reduced iron	170	180	280	410	370 6/
Hungary	1,176	1,407	1,590	1,600 e/	1,500
India:					
Pig iron	15,126	15,674	17,808	18,626	20,000
Direct-reduced iron	1,437	2,208	3,122	4,280	4,830 6/
Indonesia: Direct-reduced iron	1,370	1,500	1,620	1,860	1,800 6/
Iran:					
Pig iron	2,053	1,961	1,883	1,532	1,867 6/
Direct-reduced iron	830	1,650	2,630	3,301 r/	3,778 6/
Italy	10,462	11,066	11,157	11,684	12,000
Japan	73,144	73,738	73,776	74,905 r/	74,597 6/
Kazakstan	4,659	3,544	2,432	2,528 r/	2,536 6/
Korea, North e/	6,600	6,600	6,600	6,600	6,600
Korea, Republic of	19,323	22,000 e/	21,169 r/	22,344 r/	23,010
Libya: Direct-reduced iron	846	944	852	970	862 6/
Luxembourg 9/	2,256	2,411	1,927	1,028 r/	1,200
Macedonia e/	20	20	20	20	20
Malaysia: Direct-reduced iron	550	710	990	1,090	1,048 6/
Mexico:					
Pig iron	3,404	3,423	3,500	4,142 r/	4,200
Direct-reduced iron	2,440	2,730	3,240	3,691 r/	3,900 6/
Morocco e/	15	15	15	15	15
Netherlands 9/	4,847 r/	5,404 r/	5,443 r/	5,647 r/	5,600
New Zealand	625	653	563	631	650
Nigeria: Direct-reduced iron	53	39	40	36 r/	20
Norway	70	73	70 e/	70 e/	70
Pakistan e/	1,100	1,200	1,045 r/ 6/	1,100 r/	1,500
Paraguay	92	81	90 r/	103 r/	100

See footnotes at end of table.

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TABLE 10--Continued
PIG IRON 1/ AND DIRECT-REDUCED IRON: 2/ WORLD PRODUCTION, BY COUNTRY 3/ 4/

(Thousand metric tons)

Country 5/	1992	1993	1994	1995	1996 e/
Peru:					
Pig iron	147	147	150	150 e/	150
Direct-reduced iron	30	--	20	3	20 6/
Poland	6,498	6,298	7,082	7,373 r/	7,400
Portugal	402	398	415 e/	416 r/	400
Qatar: Direct-reduced iron	617 r/	573 r/	600	630	635
Romania	3,111	3,189	3,496	4,203	4,200
Russia:					
Pig iron	45,824	40,871	36,116	39,762	36,061 6/
Direct-reduced iron	1,580	1,540	1,710	1,680	1,500 6/
Saudi Arabia: Direct-reduced iron	1,610	2,015	2,111	2,129	2,296 6/
Serbia and Montenegro	512	62	17	120 e/	150
Slovakia 7/	XX	3,210 r/	3,330 r/	3,300 r/	3,300
South Africa:					
Pig iron	7,352 r/	6,940 r/	6,982 r/	7,137 r/	6,876 6/
Direct-reduced iron	910	870	935 r/	913 r/	960 6/
Spain	5,076	5,394	5,447	5,128 r/	5,200
Sweden	2,735	2,845	3,037	3,020 r/	3,000
Switzerland	110	110	110 e/	100 e/	100
Taiwan	5,292	6,116	5,941	6,056 e/	6,050
Trinidad and Tobago: Direct-reduced iron	680	730	940	1,050	1,070 6/
Tunisia	158	165	154	162	145 6/
Turkey	4,508	4,353	4,604	4,600 e/	5,000
Ukraine	34,663	26,999	21,200 r/	20,000 r/	18,143 6/
United Kingdom	11,542	11,534	11,943	12,238	12,225
United States:					
Pig iron	47,400	48,200	49,400	50,900	49,400 6/
Direct-reduced iron	390	440	480	460	450 6/
Venezuela: Direct-reduced iron	4,230	4,510	4,710	4,720	5,340 6/
Zimbabwe	507	211	100 e/	209 r/	210
Grand total	524,000 r/	531,000 r/	543,000 r/	564,000 r/	562,000
Of which:					
Pig iron	503,000 r/	507,000 r/	516,000 r/	533,000 r/	529,000
Direct-reduced iron	20,500	23,600	27,300 r/	30,800 r/	32,900

e/ Estimated. r/ Revised. XX Not applicable.

1/ Production is pig iron unless otherwise specified.

2/ Direct-reduced iron is obtained from ore by reduction of oxides to metal without melting.

3/ Table excludes ferroalloy production except where otherwise noted. Table includes data available through June 4, 1997.

4/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

5/ In addition to the countries listed, Vietnam has facilities to produce pig iron and may have produced limited quantities during 1992-96, but output is not reported and available information is inadequate to make reliable estimates of output levels.

6/ Reported figure.

7/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

8/ Dissolved Dec. 31, 1992.

9/ Includes blast furnace ferroalloys.

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TABLE 11
RAW STEEL: 1/ WORLD PRODUCTION, BY COUNTRY 2/ 3/

(Thousand metric tons)

Country 4/	1992	1993	1994	1995	1996 e/
Albania e/	20 r/	19 r/	19 r/	22 r/	20
Algeria	842	865 e/	808	827	675
Angola e/	10	9	9	9	9
Argentina	2,700	2,886	3,289	3,617	3,650
Australia	6,803	7,853	8,424	8,447 r/	8,295 5/
Austria	3,953	4,149	4,405 r/	4,537 r/	4,500
Azerbaijan	385	228	36 r/	12 r/	80
Bangladesh 6/	36	32	34 e/	36 e/	37
Belarus	1,105	946	880	744	886
Belgium	10,377	10,173	11,319	11,606	11,600
Benin e/	8	2	--	--	--
Bosnia and Herzegovina e/	135	115	100	115	115
Brazil 7/	23,934 r/	25,207 r/	25,747	25,076	25,700
Bulgaria	1,551	1,941	2,491	2,724 r/	2,483 5/
Burma	10 r/	11 r/	17 r/	24 r/	25
Canada	13,924	14,300	13,897	14,415	14,500
Chile 7/	1,013	1,063	1,030 r/	1,013	1,010
China e/	80,940	89,560	92,610	95,360 r/	100,000
Colombia	657	687	693 r/	714 r/	677 p/
Croatia	102	74	63 r/	45 r/	50
Cuba e/	134	90	131	207 5/	231 p/
Czech Republic 8/	XX	6,744 r/	7,093 r/	7,189 r/	7,000
Czechoslovakia 9/	10,520	XX	XX	XX	XX
Denmark	591	603	723	654 e/	650
Dominican Republic	33	--	--	--	37 p/
Ecuador	20	27	22 r/	22 r/	22
Egypt	2,524	2,772	2,622	2,642	2,620
El Salvador e/	28	37	40	10 5/	10
Finland	3,076	3,256	3,420	3,180 e/	3,200
France	17,961	17,179	18,028	18,096	18,000
Georgia	529	215	141	84 e/	80
Germany	39,711	37,625	40,847	42,100 e/	42,000
Greece	923	980	848	939	950
Guatemala	25	18	18 e/	18 e/	19
Hong Kong e/	350	350	350	350	350
Hungary	1,541 r/	1,752	1,937 r/	1,865 r/	1,800
India	18,117	18,155	19,285	20,291	20,000
Indonesia	3,171	1,948	3,220	3,500 e/	3,400
Iran	2,940	3,672	4,498	4,696	5,420
Iraq e/	100	300	300	300	300
Ireland	257	326	316 r/	310 e/	300
Israel	109	120	180 r/	200 r/	200
Italy	24,904	25,701	26,114	27,766	28,000
Jamaica e/	25 r/ 5/	25	25	25 r/	25
Japan	98,132	99,623	98,295	101,640	98,801 5/
Jordan	30	30	30 e/	30 e/	30
Kazakstan	5,675	4,279	2,969	2,963 r/	3,140
Kenya e/	20	20	20	20	20
Korea, North e/	8,100	8,100	8,100	8,100	8,100
Korea, Republic of	28,054	33,000	33,745	36,772	38,900
Latvia	246	300	332	350 e/	350
Libya	789	920	874	909 r/	863
Luxembourg	3,068	3,293	3,092	3,079 r/	2,501 5/
Macedonia	171 r/	137	67 r/	32 r/	30
Malaysia	1,559	1,808	2,046	2,450 r/	2,600
Mauritania	7	7	7 e/	5 e/	5
Mexico	8,460	9,189	10,260	12,128	12,500
Moldova	619	604	453	299	643
Morocco e/	7	7	7	7	5
Netherlands	5,438	6,001	6,174	6,409	6,330
New Zealand	759	853	766	842	900
Nigeria e/	200	150	58	36	20
Norway	446	505	456	470 e/	450

See footnotes at end of table.

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TABLE 11--Continued
RAW STEEL: 1/ WORLD PRODUCTION, BY COUNTRY 2/ 3/

(Thousand metric tons)

Country 4/	1992	1993	1994	1995	1996 e/
Pakistan	1,000 e/	1,100 e/	344	409	500
Paraguay	86	86	85 r/	96 r/	95
Peru	343	417	506	515 e/	510
Philippines	497	623	473	500 e/	500
Poland	9,867	9,937	11,113	11,890	11,500
Portugal	769	775	749	817 r/	800
Qatar	588	620	572	606	616 5/
Romania	5,376	5,446	5,800	6,555	6,500
Russia	67,029	58,346	48,812	51,300	49,200
Saudi Arabia	1,825	2,318	2,411	2,451	2,683 5/
Serbia and Montenegro	665	183	137	180 r/ e/	200
Singapore e/	500	500	500	500	500
Slovakia 8/	XX	3,768	3,948	3,255 r/	3,200
Slovenia	401 r/	355 r/	424 r/	407 r/	400
South Africa	8,970 r/	8,655 r/	8,236 r/	8,953 r/	7,909 5/
Spain	12,295	12,646	13,574	13,937 r/	14,000
Sri Lanka e/	30	30	30	30	30
Sweden	4,356	4,591	4,952	4,926 r/	5,000
Switzerland	1,208	1,260	800 e/	1,000 e/	1,000
Syria e/	70	70	70	70	70
Taiwan	10,705	12,038	11,590	11,605	12,000
Thailand	779	954	1,460	1,500 e/	1,500
Trinidad and Tobago	553	519	631	735 r/	695 p/
Tunisia	181	183	184	201	187 5/
Turkey	10,343	11,519	12,074	12,745	13,400
Uganda e/	30	30	30	35	55
Ukraine	41,759	32,357	23,798 r/	22,309	22,300
United Kingdom	16,212	16,625	17,286	17,604 r/	18,220 5/
United States	84,300	88,800	91,200	95,200	94,700 5/
Uruguay	55	36	36	40	40
Uzbekistan	630	573	364	352 e/	451
Venezuela	3,489	3,392	3,524	3,568 r/	3,730
Vietnam	219	270	300 e/	320 e/	310
Zimbabwe	547	221	187	210 e/	212
Total	724,000	730,000	730,000	755,000 r/	758,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Steel formed in solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

3/ Table includes data available through July 9, 1997.

4/ In addition to the countries listed, Ghana and Mozambique are known to have steelmaking plants, but available information is inadequate to make reliable estimates of output levels.

5/ Reported figure.

6/ Data for year ending June 30 of that stated.

7/ Excludes castings.

8/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

9/ Dissolved Dec. 31, 1992.

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IRON AND STEEL SCRAP

By Michael Fenton

Iron and steel scrap is a vital raw material for the production of new steel and cast-iron products. Because of the ready availability of scrap from manufacturing operations and from the recovery of products that are no longer used or needed, the steel and the foundry industries in the United States have been structured to recycle scrap and, as a result, are highly dependent upon it.

The recycling of steel scrap plays an important role in the conservation of energy because remelting of scrap requires much less energy than the production of iron or steel products from iron ore. In addition, the consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment.

Environment

Steel mills receiving ferrous scrap were increasingly exposed without warning to radioactive materials at an alarming rate. Of particular concern were radioactive gauges that were discarded or lost by manufacturing operations, medical centers, or the military. These radioactive objects, when shielded by lead, can pass through sensitive radiation detection devices used by electric-arc furnace steel producers. Since 1981, 24 accidental radioactive material meltings have occurred and more than 300 batches of radioactive scrap have been discovered before they were melted. Costs of accidental meltings include as much as $4 million for plant decontamination, as much as $15 million for disposing and storing radioactive baghouse dust, and as much as $13 million in lost sales revenues. Nucor Corp. reported discovery of a shielded source of cesium-137 in scrap at its truck scale, thereby avoiding a cleanup having an estimated cost of between $3 million and $21 million (Metal Bulletin Monthly, 1995). In July, the U.S. Nuclear Regulatory Commission (NRC) -State Working Group on Regulation of Radioactive Materials released recommendations concerning the problem (Steel Manufacturers Association, unpublished data accessed June 27, 1997, on the World Wide Web at URL http:steelnet.org/sma/radscrap.html). In response, the Steel Manufacturers Association informed members of the House and Senate appropriations subcommittee with jurisdiction over the NRC of the potential health, safety, and economic effects melted radioactive devices can have on the steel industry (Steel Manufacturers Association, unpublished data accessed June 27, 1997, on the World Wide Web at URL http://www.steelnet.org/sma/environ.html). Other radioactive sources are scrap pipe used in oil-drilling operations and scrap from decommissioned nuclear power and U.S. Department of Energy (DOE) facilities. In September, the DOE adopted a policy that encourages recycling and fabrication of radioactively contaminated carbon steel into one-time-use containers for disposal of low-level wastes (U.S. Department of Energy, unpublished data accessed Aug 11, 1997, on the World Wide Web at URL http://www.em.doe.gov/recyc/ presbref.html). TheUnited Nations Environment Programme's Basel Convention was established in 1992 to ban the transport of so-called hazardous wastes to poor countries having little ability to deal with them. The Technical Working Group (TWG) was formed to decide which materials should be classed as hazardous, how to define this, and which should be exempted from the ban. In December 1995, the TWG determined that iron and steel scrap should be exempted from the ban so long as it is not contaminated with materials considered hazardous; this was affirmed in April 1996.

On November 27, the U.S. Environmental Protection Agency proposed to regulate fine particulate matter smaller than 2.5 microns for the first time (Steel Manufacturers Association, 1997). According to the Steel Manufacturers Association, the effect of this would be to force steel companies to install additional expensive control equipment or to reduce production (Steel Manufacturers Association, 1997). Reduced production could result in the elimination of thousands of jobs in the steel industry and force steel consumers to acquire imports from countries that have few or no environmental regulations comparable to those of the United States. The result would be an increase in global pollution and a negative impact on the U.S. trade balance.

Consumption

Domestic data for ferrous scrap were derived from voluntary monthly or annual surveys of U.S. scrap consuming operations by the U.S. Geological Survey. For manufacturers of pig iron and raw steel, about 65% of the known establishments responded to the surveys. Their responses represented about 71% of estimated total scrap consumption by this class of consumers. The remaining 29% of scrap consumption was estimated on the basis of prior reports. For manufacturers of steel castings, iron foundries, and miscellaneous users, about 33% of the surveyed establishments responded to the annual survey, representing about 60% of estimated scrap consumption by these consumers. Total consumption for these two classes of consumers was estimated by using statistical methods and prior reports. Actual survey data accounted for about 62% of total estimated scrap consumption by all classes of scrap consumers.

Brokers, dealers, and other outside sources supplied

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domestic consumers with 51 million metric tons of all types of ferrous scrap at an estimated delivered value of nearly $6.7 billion and exported 8.4 million tons (excluding used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) valued at $1.3 billion. In 1995, domestic consumers received 50.0 million tons at a delivered value of about $6.8 billion; exports totaled 10.4 million tons valued at $1.7 billion. This represented a tonnage increase of about 2% for received quantities and a tonnage decrease of about 19% for exported quantities. The total value of received and exported scrap grades decreased nearly 6% from that of 1995.

Raw steel production was 95.5 million tons in 1996 compared with 95.2 million tons in 1995. The shares of raw steel produced by electric and basic oxygen furnaces were 42% and 58%, respectively, with electric furnace production increasing by 2%. Continuous cast steel production represented 93% of total raw steel production compared with 91% in 1995. Raw steel production capability was 105 million tons compared with 102 million tons in 1995. Raw steel capability utilization was 90.7% compared with 93.3% in 1995.

Steel mills accounted for 80% of all scrap received from brokers, dealers, and other outside sources; iron foundries and miscellaneous users received nearly 15%, and steel foundries received about 4%. The apparent total domestic consumption of ferrous scrap comprised 51 million tons net receipts (total receipts minus shipments) and 20 million tons of home scrap. Stocks of ferrous scrap at consumers' plants increased nearly 24% to 5.2 million tons. Total domestic consumption was 72 million tons, the same as that of 1995. The total market for U.S. produced scrap (net receipts plus exports minus imports) was 56.8 million tons compared with 59.3 million tons (revised) in 1995. Feedstock used by all steel and iron product manufacturers comprised scrap, 94%; pig iron, 4%; and direct reduced iron (DRI), 2%. Consumption of DRI was 16% less than that of 1995.

Net shipments of all grades of steel mill products were 91.2 million tons, an increase of 3.2% over the 88.4 million tons shipped in 1995. Imports of steel mill products increased from 22.1 million tons in 1995 to 26.5 million tons. Exports of steel mill products decreased from 6.4 million tons in 1995 to 4.6 million tons. The U.S. apparent supply of steel mill products increased from 102.3 million tons (revised) in 1995 to 108 million tons. As a share of the U.S. market, imports of steel mill products increased from 21% in 1995 to 25%. Pig iron production decreased from 50.9 million tons in 1995 to 48.5 million tons. As reported by the Bureau of the Census, iron castings shipments, totaled an estimated 9.7 million tons, compared with 9.8 million tons (revised) in 1995. Steel castings shipments (including investment castings) totaled 1.2 million tons, compared with 1.1 million tons (revised) in 1995.

Transportation

Transportation of scrap metal continued to be an important issue to steelmakers and suppliers of raw materials. Increasingly, new minimills with electric furnaces were being located beyond historical steelmaking areas, resulting in significant changes in movements of scrap and alternate iron sources. Inconsistent railroad freight-car availability was a continuing problem that hampered incoming shipments of scrap and outgoing shipments of finished steel. Railroads increased freight rates dramatically and demanded specific levels of guaranteed business. Some producers resorted to purchase or lease of their own rail cars, trucks, and barges in an attempt to solve the problems of increasing transportation costs and irregular supply of rail cars. Others were considering joining partnerships with other shippers or scrap users to reduce shipping costs.

Prices

The average composite delivered price per metric ton for No. 1 heavy melting steel scrap, calculated from prices per long ton published monthly by American Metal Market, was $130.66, ranging from a low of $113.32 in November to a high of $141.16 in February. The average composite delivered price per metric ton of No. 1 heavy melting steel scrap, calculated from prices per long ton published weekly in Iron Age Scrap Price Bulletin, was $126.02, ranging from $106.95 in November to $134.02 in February. The average composite price published in American Metal Market for No. 1 heavy melting steel scrap was lower than that of 1995 by 3.2%. Prices published in Iron Age Scrap Price Bulletin fell by 4.0%.

Based on weekly quotations by Iron Age Scrap Price Bulletin for 18-8 (18% chromium, 8% nickel) stainless steel scrap (bundles and solids) delivered to consumers in the Pittsburgh, PA, area, the average price decreased 20% from $1,045 per ton in 1995 to $831 per ton.

The average value of total ferrous scrap exports (excluding used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) increased 14% to nearly $163 per ton compared with that of 1995. The average value of total imports increased almost 8% to nearly $140 per ton.

Foreign Trade

Foreign trade valuation continued to be reported on f.a.s. (free alongside ship) basis for exports and on customs value basis for imports. The U.S. trade surplus for all classes of ferrous scrap (including used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) was $964,000 and 5.6 million tons (Bureau of the Census, unpub. data, 1996). This represented a decrease of 31% in value and 32% in quantity compared with the 1995 surplus of $1,393 million and 8.2 million tons.

Total U.S. exports of carbon steel and cast-iron scrap (excluding used rails for rerolling and other uses; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) went to 61 countries (19% annual decrease) and totaled 7.46 million tons (21% decrease) valued at $988 million (22% decrease) for an average of $132 per ton (Bureau of the Census, unpub. data, 1996). The largest tonnages went to the Republic

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of Korea, 2.51 million tons; Mexico, 923,000 tons; Canada, 870,000 tons; Turkey, 852,000 tons; Malaysia, 607,000 tons; and India, 409,000 tons. These countries received 83% of the total quantity, valued at $787 million, which was 80% of the total value.

Total U.S. exports of stainless steel scrap went to 42 countries (the same number as in 1995) and consisted of 303,382 tons (18% decrease) valued at $234 million (28% decrease) averaging $770 per ton (13% decrease) (Bureau of the Census, unpub. data, 1996). The largest tonnages went to the Republic of Korea, 79,100 tons; Spain, 64,800 tons; Canada, 54,400 tons; Taiwan, 41,500; and Japan, 25,900 tons. These countries received 88% of the total quantity, valued at $201 million, which was 86% of the total value.

U.S. exports of alloy steel scrap (excluding stainless steel) in 1996 were shipped to 43 countries (1 less than in 1995) and consisted of 674,000 tons (1% decrease) valued at $123 million (8% increase) for an average of $183 per ton (10% increase) (Bureau of the Census, unpub. data, 1996). The largest tonnages went to Canada, 321,000 tons (2% increase) and Mexico, 270,000 tons (26% increase). These countries received 88% of the total quantity, valued at $79.3 million, which was 64% of the total value.

World Review

Iron and steel scrap is an important raw material for the steel and foundry industries. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars and consumer durables, and manufacturing operations, the mature industrialized economies are the main exporters of scrap. The main trade flows of scrap are from heavily industrialized and developed countries of North America and northern Europe to the lesser developed countries of southern Europe and the Pacific rim. The United States continued to be the leading exporting country of iron and steel scrap in 1996, as reported by the International Iron and Steel Institute (1997). Other major exporters of ferrous scrap were France, Germany, the Netherlands, and the United Kingdom. The most significant importing nations were, in decreasing order of importance, Turkey, Italy, the Republic of Korea, Spain, Belgium-Luxembourg, and the Netherlands. Other Asian importers were China, India, and Japan, which individually imported only about one-fourth of that imported by the Republic of Korea.

Outlook

The demand for steel, both domestically and worldwide, will continue to be the major influence on the ferrous scrap market. Allowing for minor temporary softening of economies, worldwide steel production and consumption are expected to increase over the long term, primarily as a result of economic growth in the developing countries of Asia, Russia and the Commonwealth of Independent States, eastern Europe, and Latin America. As more steel is produced worldwide in electric furnaces and as integrated mills increase usage of scrap in blast furnaces, demand for scrap supplies will increase. Total electric furnace production may increase as much as 28 million tons per year in China, Indonesia, Malaysia, the Republic of Korea, Taiwan, and Thailand. Growing demand for scrap supplies is also expected in Brazil, India, and Turkey. Domestically, scrap demand will increase in the United States as mills under construction along the Mississippi River are completed, which will cause scrap exports to decrease and imports to increase.

Significant long-term scrap shortages might be expected to develop, as pressure on the scrap market increases. Nevertheless, raw materials demand should be met, either as scrap or as scrap alternatives. In the United States and the emerging industrial counties, the supply of scrap is anticipated to increase as recycling continues to improve. In the United States, for example, the primary feedstock for obsolete grades is the automobile, and virtually every car used is recycled. The recycling rate of obsolete appliance scrap has increased from 2% in 1988 to 75% in 1995 and is expected to increase as environmental regulations increase and recycling becomes more profitable and convenient. The recycling rate of steel cans has increased from 15% in 1988 to 56% in 1995. Nucor-Yamato Steel may be a trend setter as the first facility to recycle nearly all byproducts of steel production, including electric furnace dust, mill scale, and sludge.

Quality is of paramount importance in today's electric steelmaking, which will require higher quality scrap and increasing demand for alternative iron sources. Scrap processors will use more sophisticated sampling, analytical, and computer systems for more careful sorting and optimizing the value of scrap. Cooperation between scrap dealers and consumers will increase in order to provide the best quality scrap requested for specific uses. Increasingly, scrap suppliers are becoming certified in quality-assurance programs. The ISO-9000 and 9002 programs are concerned with product quality, and the ISO-14000 program is designed to avoid environmental damage. Whether or not scrap supply becomes short, interest in alternative iron sources will continue because of the growth of electric furnace steel production and the need to avoid the influence of residual elements on product performance. Production of DRI, increasing steadily during the past three decades, reached a new high in 1996 and may increase an additional 33% by 2000. Basic-grade pig iron from integrated mills has become and perhaps will increasingly be a standard feed in the electric furnaces.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines

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TABLE 1
SALIENT U.S. IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON STATISTICS 1/

(Thousand metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
Manufacturers of pig iron and raw steel and castings: 2/						
Ferrous scrap consumption		50,000	53,000	54,000	56,000	56,000
Pig iron consumption		47,000	48,000	50,000	51,000	50,000
Direct-reduced iron consumption		1,100	1,500	1,500	1,500	1,300
Net receipts of ferrous scrap 3/		33,000	37,000	40,000	42,000	41,000
Home scrap production 4/		17,000	16,000	14,000	15,000	15,000
Ending stocks of ferrous scrap, Dec. 31		3,100	3,200	3,600	3,700	4,800
Manufacturers of steel castings: 5/						
Ferrous scrap consumption		1,600	1,900	2,000	2,000	2,700
Pig iron consumption		13	9	10	10	11
Net receipts of ferrous scrap 3/		1,100	1,300	1,400	1,300	2,000
Home scrap production 4/		530	610	660	680	640
Ending stocks of ferrous scrap, Dec. 31		170	86	95	93	95
Iron foundries and miscellaneous users: 5/						
Ferrous scrap consumption		11,000	13,000	14,000	13,000	13,000
Pig iron consumption		620	670	1,000	1,100	1,100
Direct-reduced iron consumption		11	3	2	W	W
Net receipts of ferrous scrap 3/		8,000	7,900	8,400	8,300	8,300
Home scrap production 4/		3,300	4,600	5,100	4,900	4,900
Ending stocks of ferrous scrap, Dec. 31		520	370	370	390	360
Totals, all manufacturing types:						
Ferrous scrap consumption		63,000	68,000	70,000	72,000	72,000
Pig iron consumption		48,000	49,000	51,000	52,000	52,000
Direct-reduced iron consumption		1,100	1,500	1,500	1,500	1,300
Net receipts of ferrous scrap 3/		42,000	46,000	50,000	51,000	51,000
Home scrap production 4/		21,000	22,000	20,000	20,000	20,000
Ending stocks, Dec. 31:						
Ferrous scrap at consumer plants		3,800	3,700	4,100	4,200	5,200
Pig iron at consumer and supplier plants		180	220	400	620 r/	600
Direct-reduced iron at consumer plants		130	200	240	190 r/	270
Exports: 6/						
Ferrous scrap (includes tinplate and terneplate) 7/		9,260	9,810	8,810	10,400	8,440
Value	thousands	$1,100,000	$1,320,000	$1,270,000	$1,700,000	$1,340,000
Pig iron (all grades)		33	27	56	54	48
Value	thousands	$3,200	$3,040	$6,780	$6,450	$7,040
Direct-reduced iron (steelmaking grade)		9	17	17	5	3
Value	thousands	$2,020	$1,860	$1,850	$490	$304
Imports for consumption: 6/						
Ferrous scrap (includes tinplate and terneplate) 7/		1,320	1,390	1,740	2,090	2,600
Value	thousands	$148,000	$162,000	$218,000	$284,000	$342,000
Pig iron (all grades)		497	828	2,500	2,360	2,520
Value	thousands	$72,800	$117,000	$344,000	$391,000	$390,000
Direct-reduced iron (steelmaking grade)		542	1,090	1,170	1,190	1,050
Value	thousands	$54,000	$104,000	$138,000	$145,000	$136,000

r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to two significant digits, except trade data which are rounded to three significant digits; may not add to totals shown. Data are not entirely comparable due to changes in collection and estimation methods in 1993.

2/ Includes manufacturers of raw steel that also produce steel castings.

3/ Net receipts of scrap is defined as receipts from brokers, dealers, and other outside sources, plus receipts from other own-company plants, minus shipments.

4/ Home scrap production includes recirculating scrap resulting from current operations and obsolete home scrap.

5/ Some consumers in the "Manufacturers of steel castings" category also produce iron castings; some consumers in the "Iron foundries and miscellaneous users" category also produce steel castings.

6/ Data from Bureau of the Census. Export valuation is "free alongside ship" (f.a.s.) value, and import valuation is customs value.

7/ Excludes used rails for rerolling and other uses, and ships, boats and other vessels for scrapping.

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TABLE 2
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 1996, 1/ BY GRADE

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of both purchased and home scrap	Shipments of scrap	Ending stocks, Dec. 31
	From brokers, dealers and other outside sources	From other own-company plants	Recirculating scrap from current operations	Obsolete scrap 2/			
Manufacturers of pig iron and raw steel and castings:							
Carbon steel:							
Low-phosphorus plate and punchings	420	--	1	--	380	41	18
Cut structural and plate	3,500	21	760	51	4,200	49	350
No. 1 heavy melting steel	6,600	270	3,900	110	11,000	130	750
No. 2 heavy melting steel	5,000	54	660	10	5,700	5	460
No. 1 and electric furnace bundles	5,700	390	1,600	(3/)	6,900	840	480
No. 2 and all other bundles	1,100	14	2	--	1,100	--	73
Electric furnace, 1 foot and under (not bundles)	19	4	150	--	110	60	1
Railroad rails	140	--	42	--	190	1	6
Turnings and borings	2,000	9	160	(3/)	2,200	(3/)	120
Slag scrap	790	110	1,400	4	2,200	210	170
Shredded or fragmentized	7,200	1,000	330	--	8,700	15	510
No. 1 busheling	3,800	77	120	--	3,800	87	250
Steel cans (post consumer)	250	17	64	--	350	--	76
All other carbon steel scrap	2,100	41	3,200	8	4,800	540	390
Stainless steel scrap	580	12	440	(3/)	1,000	8	43
Alloy steel (except stainless)	160	87	510	--	720	9	75
Ingot mold and stool scrap	18	--	130	97	96	140	23
Machinery and cupola cast iron	71	--	4	--	60	1	4
Cast-iron borings	200	--	(3/)	(3/)	190	(3/)	11
Motor blocks	8	--	--	--	(4/)	--	(4/)
Other iron scrap	470	52	440	--	970	150	370
Other mixed scrap	890	4	490	--	1,200	90	610
Total	41,000	2,200	14,000	280	56,000	2,400	4,800
Manufacturers of steel castings:							
Carbon steel:							
Low-phosphorus plate and punchings	770	(3/)	64	(3/)	860	(3/)	19
Cut structural and plate	190	1	6	(3/)	200	(3/)	16
No. 1 heavy melting steel	100	13	90	--	210	4	8
No. 2 heavy melting steel	11	--	10	--	24	--	(3/)
No. 1 and electric furnace bundles	31	--	--	--	27	--	4
No. 2 and all other bundles	--	--	--	--	--	--	--
Electric furnace, 1 foot and under (not bundles)	1	5	(3/)	--	6	--	(3/)
Railroad rails	12	--	1	--	13	6	1
Turnings and borings	40	--	8	--	48	--	1
Slag scrap	6	--	2	--	13	--	(3/)
Shredded or fragmentized	75	--	--	--	76	--	2
No. 1 busheling	93	--	7	--	100	--	3
Steel cans (post consumer)	3	--	30	--	34	--	(3/)
All other carbon steel scrap	140	--	300	2	440	(3/)	7
Stainless steel scrap	390	--	34	(3/)	430	2	15
Alloy steel (except stainless)	78	(3/)	63	--	140	(3/)	9
Ingot mold and stool scrap	10	--	--	(3/)	9	(3/)	1
Machinery and cupola cast iron	--	--	(3/)	--	(3/)	--	(3/)
Cast-iron borings	(3/)	--	1	--	1	--	(3/)
Motor blocks	(3/)	--	(3/)	--	(3/)	--	(3/)
Other iron scrap	10	--	8	(3/)	18	1	2
Other mixed scrap	53	--	2	14	68	1	4
Total	2,000	19	620	17	2,700	13	95

See footnotes at end of table.

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TABLE 2--Continued
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 1996, 1/ BY GRADE

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of both purchased and home scrap	Shipments of scrap	Ending stocks, Dec. 31
	From brokers, dealers and other outside sources	From other own-company plants	Recirculating scrap from current operations	Obsolete scrap 2/			
Iron foundries and miscellaneous users:							
Carbon steel:							
Low-phosphorus plate and punchings	810	8	96	(3/)	910	(3/)	16
Cut structural and plate	1,200	53	6	(3/)	1,300	(3/)	49
No. 1 heavy melting steel	260	4	18	(3/)	280	2	8
No. 2 heavy melting steel	150	(3/)	--	--	150	--	3
No. 1 and electric furnace bundles	120	140	32	--	280	--	13
No. 2 and all other bundles	180	--	1	--	180	1	4
Electric furnace, 1 foot and under (not bundles)	140	1	1	--	140	1	3
Railroad rails	160	--	9	(3/)	180	--	7
Turnings and borings	60	65	3	--	130	4	4
Slag scrap	61	--	5	--	63	3	3
Shredded or fragmentized	1,400	97	(3/)	--	1,500	--	53
No. 1 busheling	820	91	38	--	910	38	23
Steel cans (post consumer)	15	--	--	--	15	--	(3/)
All other carbon steel scrap	110	(3/)	31	--	140	(3/)	6
Stainless steel scrap	5	--	5	--	9	(3/)	2
Alloy steel (except stainless)	12	--	1	--	13	--	2
Ingot mold and stool scrap	92	--	97	--	190	--	10
Machinery and cupola cast iron	740	--	270	2	1,000	2	50
Cast-iron borings	300	83	36	1	410	10	7
Motor blocks	290	9	650	--	940	(3/)	16
Other iron scrap	290	320	3,300	--	3,900	7	62
Other mixed scrap	320	4	250	(3/)	590	1	22
Total	7,500	880	4,800	3	13,000	68	360
Totals for all manufacturing types:							
Carbon steel:							
Low-phosphorus plate and punchings	2,000	8	160	(3/)	2,100	42	53
Cut structural and plate	4,900	75	770	51	5,700	49	420
No. 1 heavy melting steel	7,000	290	4,000	110	11,000	140	770
No. 2 heavy melting steel	5,200	54	670	10	5,900	5	460
No. 1 and electric furnace bundles	5,900	530	1,700	(3/)	7,200	840	490
No. 2 and all other bundles	1,300	14	3	--	1,300	1	77
Electric furnace, 1 foot and under (not bundles)	160	9	150	--	250	60	4
Railroad rails	320	--	52	(3/)	380	1	13
Turnings and borings	2,100	74	170	(3/)	2,400	4	130
Slag scrap	860	110	1,400	4	2,300	220	170
Shredded or fragmentized	8,600	1,100	330	--	10,000	15	570
No. 1 busheling	4,700	170	170	--	4,800	120	270
Steel cans (post consumer)	270	17	95	--	400	--	77
All other carbon steel scrap	2,300	41	3,500	10	5,400	540	410
Stainless steel scrap	980	12	480	(3/)	1,500	10	59
Alloy steel (except stainless)	250	87	570	--	880	9	86
Ingot mold and stool scrap	120	--	230	97	300	140	35
Machinery and cupola cast iron	810	--	280	2	1,100	3	54
Cast-iron borings	500	83	37	1	610	10	17
Motor blocks	300	9	650	(3/)	950	(3/)	17
Other iron scrap	760	380	3,700	(3/)	4,900	150	430
Other mixed scrap	1,300	7	740	14	1,900	91	630
Total	51,000	3,100	20,000	300	72,000	2,500	5,200

1/ Data are rounded to two significant digits; may not add to totals shown.
2/ Obsolete home scrap includes ingot molds, stools, and scrap from old equipment, buildings, etc.
3/ Less than 1/2 unit.
4/ Withheld to avoid disclosing company proprietary data; included with "Other iron scrap."

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TABLE 3
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF PIG IRON AND DIRECT-REDUCED IRON IN 1996 1/

(Thousand metric tons)

	Receipts	Production	Consumption	Shipments	Stocks, Dec. 31
Manufacturers of pig iron, raw steel, and castings:					
Pig iron	9,200 2/	45,000	50,000	2,800	520
Direct-reduced iron	1,300 3/	--	1,300	W	270
Manufacturers of steel castings:					
Pig iron	11	--	11	(4/)	1
Direct-reduced iron	--	--	--	--	--
Iron foundries and miscellaneous users:					
Pig iron	1,100	--	1,100	19	79
Direct-reduced iron	W	--	W	--	(4/)
Totals for all manufacturing types:					
Pig iron	10,000	45,000	52,000	2,800	600
Direct-reduced iron	1,300	--	1,300	W	270

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to two significant digits; may not add to totals shown.
2/ Includes 1,900 tons purchased by electric furnace steel producers.
3/ Includes 7,300 tons purchased by integrated steel producers.
4/ Less than 1/2 unit.

TABLE 4
U.S. CONSUMPTION OF IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON (DRI) IN 1996, BY TYPE OF FURNACE OR OTHER USE 1/

(Thousand metric tons)

	Manufacturers of pig iron and raw steel and castings			Manufacturers of steel castings			Iron foundries and miscellaneous users			Totals for all manufacturing types		
	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI	Scrap	Pig iron	DRI
Blast furnace	1,700	--	380	--	--	--	--	--	--	1,700	--	380
Basic oxygen process	16,000	49,000	200	--	--	--	--	--	--	16,000	49,000	200
Electric furnace	38,000	1,600	710	2,700	11	--	5,100	580	--	46,000	2,200	710
Cupola furnace	2	--	--	--	--	--	8,100	530	W	8,100	530	W
Other (including air furnaces)	4	--	--	3	--	--	(2/)	(2/)	--	23	(2/)	--
Direct castings 3/	--	42	--	--	--	--	--	--	--	--	42	--
Total	56,000	50,000	1,300	2,700	11	--	13,000	1,100	W	72,000	52,000	1,300

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to two significant digits; may not add to totals shown.
2/ Withheld to avoid disclosing company proprietary data; included with "Electric furnace."
3/ Includes ingot molds and stools.

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TABLE 5
IRON AND STEEL SCRAP SUPPLY 1/ AVAILABLE FOR CONSUMPTION IN 1996, BY REGION AND STATE 2/

(Thousand metric tons)

Region and State	Receipts of scrap		Production of home scrap		Shipments of scrap 4/	New supply available for consumption
	From brokers, dealers, and other outside sources	From other own company plants	Recirculating scrap resulting from current operations	Obsolete scrap 3/		
New England and Middle Atlantic:						
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	53	--	23	W	(5/)	76
New Jersey and New York	1,500	W	92	--	5	1,600
Pennsylvania	4,100	W	2,800	W	35	7,000
Total	5,700	110	2,900	84	35	8,700
North Central:						
Illinois	4,200	120	1,500	12	220	5,600
Indiana	4,000	160	5,000	42	610	8,600
Iowa, Nebraska, South Dakota	1,300	4	210	--	W	1,500
Kansas and Missouri	1,100	1	160	--	(5/)	1,300
Michigan	3,200	780	1,900	2	180	5,800
Minnesota	430	140	150	(5/)	W	710
Ohio	6,400	810	2,400	41	1,200	8,500
Wisconsin	1,100	4	930	(5/)	(5/)	2,100
Total	22,000	2,000	12,000	97	2,200	34,000
South Atlantic:						
Delaware and Maryland	630	1	480	--	W	1,100
Florida and Georgia	1,200	--	190	--	W	1,400
North Carolina and South Carolina	1,700	8	220	--	--	1,900
Virginia and West Virginia	1,500	130	600	W	W	2,200
Total	5,100	140	1,500	W	100	6,600
South Central:						
Alabama and Mississippi	2,600	W	810	W	W	3,400
Arkansas, Louisiana, Oklahoma	5,500	W	280	W	1	5,800
Kentucky and Tennessee	2,300	2	680	--	W	3,000
Texas	3,900	770	730	8	6	5,300
Total	14,000	830	2,500	34	100	17,000
Mountain and Pacific:						
Arizona, Colorado, Idaho, Montana, Utah	1,800	(5/)	520	W	W	2,400
California, Oregon, Washington	2,000	W	270	1	13	2,300
Total	3,800	W	790	W	W	4,700
Grand total	51,000	3,100	20,000	300	2,500	71,000

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand Total."

1/ Supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The difference in stock levels at the beginning and end of the year is not taken into consideration.

2/ Data are rounded to two significant digits; may not add to totals shown.

3/ Obsolete scrap includes ingot molds, stools and scrap from old equipment, buildings, etc.

4/ Includes scrap shipped, transferred, or otherwise disposed of during the year.

5/ Less than 1/2 unit.

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TABLE 6
U.S. CONSUMPTION OF IRON AND STEEL SCRAP 1/ AND PIG IRON 2/ IN 1996, BY REGION AND STATE 3/

(Thousand metric tons)

Region and State	Manufacturers of pig iron and raw steel and castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Totals for all manufacturing types	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,300	24	17	(4/)	390	30	1,700	54
Pennsylvania	6,200	2,900	220	3	620	84	7,000	3,000
Total	7,500	2,900	240	3	1,000	110	8,700	3,000
North Central:								
Illinois	5,100	2,600	82	1	440	33	5,600	2,700
Indiana	7,600	17,000	92	1	1,300	160	9,000	17,000
Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota, Wisconsin	2,400	3	510	2	2,300	290	5,300	300
Michigan	2,900	5,400	38	(4/)	2,800	140	5,800	5,500
Ohio	6,900	11,000	430	2	1,400	130	8,700	11,000
Total	25,000	36,000	1,200	6	8,300	760	34,000	36,000
South Atlantic:								
Delaware, Maryland, Virginia, West Virginia	2,600	4,600	4	W	590	W	3,200	4,600
Florida, Georgia, North Carolina, South Carolina	2,900	140	2	W	450	W	3,300	190
Total	5,500	4,700	6	1	1,000	70	6,500	4,800
South Central:								
Alabama, Kentucky, Mississippi, Tennessee	4,200	4,000	300	W	1,900	110	6,400	4,200
Arkansas, Louisiana, Oklahoma	4,800	W	780	W	130	W	5,700	630
Texas	4,700	W	85	W	490	W	5,300	260
Total	14,000	4,900	1,200	W	2,500	150	17,000	5,000
Mountain and Pacific:								
Arizona, Colorado, Idaho, Montana, Utah	2,300	W	21	(4/)	120	W	2,400	2,100
California, Oregon, Washington	2,000	W	130	(4/)	210	W	2,300	95
Total	4,200	2,200	150	(4/)	330	8	4,700	2,200
Grand total	56,000	50,000	2,700	11	13,000	1,100	72,000	52,000

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand Total."
1/ Includes recirculating scrap resulting from current operations and home-generated obsolete scrap.
2/ Includes molten pig iron used for ingot molds and direct castings.
3/ Data are rounded to two significant digits; may not add to totals shown.
4/ Less than 1/2 unit.

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TABLE 7
U.S. CONSUMER STOCKS OF IRON AND STEEL SCRAP AND PIG IRON, DECEMBER 31, 1996, BY REGION AND STATE 1/

(Thousand metric tons)

Region and State	Carbon steel 2/	Stainless steel	Alloy steel 3/	Cast iron 4/	Other grades of scrap	Total scrap	Pig iron
New England and Middle Atlantic:							
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	1	W	W	1	W	3	W
New Jersey and New York	84	W	W	3	W	91	W
Pennsylvania	330	33	36	34	6	440	4
Total	420	36	38	38	7	540	8
North Central:							
Illinois	320	W	W	13	W	340	19
Indiana	480	5	W	110	13	610	220
Iowa, Kansas, Missouri, Nebraska, South Dakota	130	W	5	6	7	150	14
Michigan	160	(5/)	1	17	56	230	7
Minnesota and Wisconsin	50	2	(5/)	9	1	62	39
Ohio	380	4	21	33	W	440	33
Total	1,500	11	28	190	80	1,800	330
South Atlantic:							
Delaware, Maryland, Virginia, West Virginia	190	W	W	14	6	210	W
Florida, Georgia, North Carolina, South Carolina	190	W	W	19	5	210	W
Total	370	W	W	33	11	420	110
South Central:							
Alabama, Kentucky, Mississippi, Tennessee	510	W	W	260	W	1,300	W
Arkansas, Louisiana, Oklahoma	470	10	W	2	W	490	W
Texas	360	W	11	23	W	390	32
Total	1,300	11	13	290	490	2,100	130
Mountain and Pacific:							
Arizona, Colorado, Idaho, Montana, Utah	140	(5/)	W	W	--	140	W
California, Oregon, Washington	130	1	W	W	49	190	W
Total	270	1	5	8	49	330	19
Grand total	3,900	59	86	560	630	5,200	600

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand Total."
1/ Data are rounded to two significant digits; may not add to totals shown.
2/ Excludes rerolling rails.
3/ Excludes stainless steel.
4/ Includes borings.
5/ Less than 1/2 unit.

TABLE 8
U.S. AVERAGE MONTHLY PRICE AND COMPOSITE PRICE FOR NO. 1 HEAVY MELTING STEEL, WITH ANNUAL AVERAGES FOR 1995 AND 1996 1/

(Dollars per metric ton)

Month	Chicago	Philadelphia	Pittsburgh	Composite price
January	141.14	131.04	150.72	140.97
February	142.22	131.64	147.63	140.50
March	137.30	125.47	137.72	133.50
April	137.30	125.00	134.63	132.31
May	140.25	128.75	139.71	136.23
June	137.30	128.93	136.51	134.25
July	132.38	125.98	132.38	130.24
August	134.79	124.10	135.33	131.40
September	138.13	125.98	138.13	134.08
October	128.82	116.22	131.39	125.47
November	118.85	102.51	118.60	113.32
December	118.60	107.65	118.60	114.95
Annual average:				
1996	133.92	122.77	135.11	130.60
1995	140.91	124.08	140.09	135.03

1/ Calculated by the U.S. Geological Survey from prices published in American Metal Market.

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TABLE 9
U.S. EXPORTS OF IRON AND STEEL SCRAP, 1/ BY COUNTRY 2/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Belgium	24	23,600	4	2,460
Canada	1,650	222,000	1,250	170,000
China	199	48,600	247	50,300
Colombia	24	2,520	9	1,070
Germany	3	1,080	6	1,080
Greece	25	3,340	(3/)	16
Hong Kong	106	23,900	88	22,800
India	647	95,800	418	58,800
Indonesia	45	7,470	28	4,300
Italy	125	19,700	8	6,530
Japan	709	131,000	157	45,800
Korea, Republic of	3,270	524,000	2,590	391,000
Malaysia	386	52,500	607	77,000
Mexico	821	110,000	1,190	158,000
Netherlands	16	16,100	4	2,330
Pakistan	6	1,550	2	1,390
Peru	(3/)	77	--	--
Philippines	45	8,800	90	12,500
Singapore	3	1,970	4	2,430
South Africa	26	8,950	13	11,400
Spain	88	68,600	65	49,900
Sweden	13	8,520	9	8,630
Taiwan	147	33,700	316	69,500
Thailand	423	61,500	175	23,300
Turkey	1,390	190,000	852	113,000
United Kingdom	26	5,260	4	3,060
Venezuela	144	19,100	265	47,400
Other	73	9,160	44	10,100
Total	10,400	1,700,000	8,440	1,340,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes used rails for rerolling and other uses and ships, boats and other vessels for scrapping. Export valuation is "free alongside ship" (f.a.s.) value. The U.S. exported scrap to 75 countries in 1995 and 73 countries in 1996.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 10
U.S. EXPORTS OF IRON AND STEEL SCRAP, 1/ BY CUSTOMS DISTRICT 2/

(Thousand metric tons and thousand dollars)

Customs district	1995		1996	
	Quantity	Value	Quantity	Value
Boston, MA	649	83,700	572	76,600
Buffalo, NY	104	42,500	88	32,800
Chicago, IL	18	2,030	4	907
Cleveland, OH	10	1,880	(3/)	75
Columbia - Snake	150	24,000	107	21,800
Detroit, MI	309	55,300	256	43,700
Honolulu, HI	102	15,600	95	13,900
Houston-Galveston, TX	81	54,000	53	34,300
Laredo, TX	419	52,900	570	72,400
Los Angeles, CA	1,910	337,000	1,180	205,000
Miami, FL	102	15,000	127	20,800
New Orleans, LA	94	83,800	172	62,200
New York, NY	1,950	287,000	1,170	178,000
Norfolk, VA	229	25,900	211	27,500
Pembina, ND	421	49,500	263	29,900
Philadelphia, PA	533	69,700	279	34,400
Portland, ME	310	40,600	164	20,500
Providence, RI	459	61,400	363	46,400
San Francisco, CA	918	169,000	1,050	184,000
Seattle, WA	403	70,600	390	60,100
Tampa, FL	268	38,100	343	45,000
Other	996	117,000	990	135,000
Total	10,400	1,700,000	8,440	1,340,000

1/ Excludes used rails for rerolling and other uses and ships, boats and other vessels for scrapping. Export valuation is "free alongside ship" (f.a.s.) value.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 11
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY GRADE 1/ 2/

(Thousand metric tons and thousand dollars)

Grade	1995		1996	
	Quantity	Value	Quantity	Value
No. 1 heavy melting scrap	2,400	332,000	1,920	246,000
No. 2 heavy melting scrap	735	95,200	508	61,800
No. 1 bundles	189	24,800	110	13,500
No. 2 bundles	232	28,500	126	14,200
Shredded steel scrap	2,850	410,000	2,720	370,000
Borings, shovelings and turnings	277	29,100	254	25,800
Cut plate and structural	516	75,600	559	73,500
Tinned iron or steel	88	24,700	51	18,700
Remelting scrap ingots	8	2,230	3	781
Stainless steel scrap	368	325,000	303	234,000
Other alloy steel scrap	682	114,000	674	123,000
Other steel scrap 3/	1,040	118,000	598	95,300
Iron scrap	1,050	118,000	627	68,700
Total	10,400	1,700,000	8,440	1,340,000
Ships, boats, and other vessels for scrapping	6	875	24	2,710
Used rails for rerolling and other uses 4/	23	5,960	21	6,900
Total exports	10,500	1,710,000	8,490	1,350,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Export valuation is on a "free alongside ship" (f.a.s.) value.

3/ Includes tinplate and terneplate.

4/ Includes mixed (used plus new) rails. See table 15 for details.

Source: Bureau of the Census.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY COUNTRY 1/ 2/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Bahamas, The	2	111	1	85
Belgium	(3/)	141	(3/)	24
Brazil	23	1,530	8	1,670
Canada	1,610	217,000	1,910	247,000
China	7	1,020	1	1,260
Colombia	(3/)	101	(3/)	18
Costa Rica	(3/)	8	1	91
Dominican Republic	7	836	5	884
France	1	114	(3/)	56
Germany	21	3,190	75	10,800
Israel	1	63	(3/)	255
Jamaica	9	936	4	483
Japan	67	9,630	51	8,230
Korea, Republic of	(3/)	12	(3/)	29
Martinique	--	--	1	64
Mexico	165	34,300	114	27,600
Netherlands	(3/)	8	3	3,100
Panama	4	571	12	1,930
Peru	--	--	31	450
Philippines	(3/)	77	(3/)	6
Poland	(3/)	10	--	--
Russia	13	1,640	(3/)	76
Singapore	(3/)	2	(3/)	111
South Africa	--	--	36	3,300
Switzerland	(3/)	37	(3/)	70
Trinidad and Tobago	1	140	16	712
United Kingdom	2	275	69	8,330
Venezuela	152	11,300	262	24,600
Other	1	575	1	1,250
Total	2,090	284,000	2,600	342,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes used rails for rerolling and other uses and ships, boats and other vessels for scrapping. Import valuation is customs value. The U.S. imported scrap from 42 countries in 1995 and 49 countries in 1996.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CUSTOMS DISTRICT 1/ 2/

(Thousand metric tons and thousand dollars)

Customs district	1995		1996	
	Quantity	Value	Quantity	Value
Baltimore, MD	22	1,270	22	1,430
Buffalo, NY	405	66,100	418	63,400
Charleston, SC	54	6,460	71	9,250
Chicago, IL	59	5,710	17	2,760
Cleveland, OH	59	7,210	67	6,480
Detroit, MI	887	109,000	1,200	145,000
El Paso, TX	41	5,260	45	6,240
Laredo, TX	73	21,900	49	16,400
New Orleans, LA	44	4,880	208	24,500
New York, NY	1	141	(3/)	677
Ogdensburg, NY	20	4,180	15	4,020
Pembina, ND	4	2,720	12	2,950
San Diego, CA	49	6,870	22	5,590
Seattle, WA	311	32,500	392	40,900
Other	57	9,520	67	12,600
Total	2,090	284,000	2,600	342,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes used rails for rerolling and other uses and ships, boats and other vessels for scrapping. Import valuation is customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CLASS 1/ 2/

(Thousand metric tons and thousand dollars)

Class	1995		1996	
	Quantity	Value	Quantity	Value
No. 1 heavy melting scrap	52	5,900	112	13,200
No. 2 heavy melting scrap	22	2,490	22	2,650
No. 1 bundles	208	22,800	233	27,500
No. 2 bundles	31	3,600	18	2,140
Shredded steel scrap	104	14,100	84	11,200
Borings, shovelings and turnings	124	11,500	121	12,000
Cut plate and structural	133	9,140	164	14,300
Tinned iron or steel	16	2,390	65	5,690
Remelting scrap ingots	63	9,830	82	12,900
Stainless steel scrap	43	33,800	51	28,500
Other alloy steel scrap	252	33,500	345	48,300
Other steel scrap 3/	896	112,000	1,100	137,000
Iron scrap	143	23,100	210	27,000
Total	2,090	284,000	2,600	342,000
Ships, boats, and other vessels for scrapping	(4/)	2,010	(4/)	90
Used rails for rerolling and other uses 5/	186	31,400	248	43,400
Total imports	2,270	317,000	2,890	386,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import valuation is customs value.
3/ Includes tinplate and terneplate.
4/ Less than 1/2 unit.
5/ Includes mixed (used plus new) rails. See table 16 for details.

Source: Bureau of the Census.

TABLE 15
U.S. EXPORTS OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY 1/ 2/

Country	1995		1996	
	Quantity (metric tons)	Value (thousand dollars)	Quantity (metric tons)	Value (thousand dollars)
Brazil	287	62	54	70
Canada	2,720	1,020	7,040	2,890
Chile	71	113	102	102
Dominican Republic	218	57	372	111
Italy	102	106	--	--
Japan	13	3	--	--
Malaysia	705	185	17	9
Mexico	18,100	3,860	12,400	2,830
Peru	--	--	323	148
Other	997	553	1,010	740
Total	23,200	5,960	21,300	6,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Exports contain mixed (used plus new) rails totaling 616 metric tons valued at $640,000 (revised) in 1995 and 715 metric tons valued at $548,000 in 1996. Export valuation is "free alongside ship" (f.a.s.) value.

Source: Bureau of the Census.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY 1/ 2/

Country	1995 Quantity (metric tons)	1995 Value (thousand dollars)	1996 Quantity (metric tons)	1996 Value (thousand dollars)
Australia	--	--	60	28
Canada	58,100	11,000	89,200	21,600
Germany	--	--	32	52
Italy	--	--	57	173
Japan	1,950	957	278	204
Poland	18,400	5,270	32,200	5,370
Russia	108,000	14,200	126,000	15,100
Slovakia	--	--	328	806
Other	10 r/	38 r/	16	105
Total	186,000	31,400	248,000	43,400

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import valuation is customs value.

Source: Bureau of the Census.

TABLE 17
U.S. EXPORTS OF DIRECT REDUCED IRON (DRI), BY COUNTRY 1/ 2/

Country	1995 Quantity (metric tons)	1995 Value (thousand dollars)	1996 Quantity (metric tons)	1996 Value (thousand dollars)
Argentina	319	34	--	--
Australia	803	85	1,270	134
Canada	--	--	22	3
Colombia	64	7	397	42
Germany	--	--	30	3
Japan	775	82	--	--
Italy	--	--	59	6
Korea, Republic of	--	--	321	34
Mexico	285	30	161	17
Netherlands	--	--	296	31
Other	2350 r/	252 r/	326	34
Total	4,600	490	2,880	304

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data are for steelmaking grade DRI only.

Source: Bureau of the Census.

TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF DIRECT REDUCED IRON (DRI), BY COUNTRY 1/ 2/

Country	1995 Quantity (metric tons)	1995 Value (thousand dollars)	1996 Quantity (metric tons)	1996 Value (thousand dollars)
Canada	430	47.7	117	17.2
China	1,500	159	--	--
Russia	33700	4550	--	--
Sweden	--	--	995	105
Ukraine	60300	7820	35900	4710
Venezuela	1,090,000	133000	1,010,000	131000
Total	1,190,000	145,000	1,050,000	136,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data are for steelmaking grade DRI only.

Source: Bureau of the Census.

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TABLE 19
U.S. EXPORTS OF PIG IRON, BY COUNTRY 1/ 2/

Country	1995 Quantity (metric tons)	1995 Value (thousand dollars)	1996 Quantity (metric tons)	1996 Value (thousand dollars)
Argentina	707	62	--	--
Australia	2,400	211	3,140	276
Brazil	2,770	244	--	--
Canada	3,750	894	13,000	2,750
China	82	18	364	32
Hong Kong	73	15	--	--
India	292	35	--	--
Japan	--	--	1,230	112
Korea, Republic of	1,350	119	--	--
Mexico	32,200	3,730	26,500	3,460
Netherlands	273	27	--	--
Peru	984	87	--	--
Singapore	722	64	--	--
Taiwan	--	--	1,040	92
United Kingdom	6,660	586	67	39
Venezuela	1,680	290	2,770	253
Other	484	63	234	23
Total	54,400	6,450	48,400	7,040

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes the following grades of pig iron: less than or equal to 0.5 percent phosphorus content; greater than 0.5 percent phosporus content; and alloy grade. Export valuation is "free alongside ship" (f.a.s.) value.

Source: Bureau of the Census.

TABLE 20
U.S. IMPORTS FOR CONSUMPTION OF PIG IRON, BY COUNTRY 1/ 2/

Country	1995 Quantity (metric tons)	1995 Value (thousand dollars)	1996 Quantity (metric tons)	1996 Value (thousand dollars)
Argentina	--	--	27,400	3,750
Brazil	1,530,000	253,000	1,630,000	253,000
Canada	88,100	25,400	102,000	22,900
China	57,400	8,590	21,400	2,960
Cote d'Ivoire	1,280	274	--	--
Estonia	39,400	5,910	--	--
France	--	--	20,700	2,860
Germany	--	--	39,600	5,210
Japan	37,500	5,780	35,500	4,990
Latvia	--	--	10,000	1,430
Mexico	66	15	--	--
Norway	--	--	3,000	532
Russia	256,000	38,000	261,000	35,900
South Africa	82,600	17,100	113,000	20,000
Swaziland	49	15	--	--
Switzerland	17,100	3,600	--	--
Turkey	--	--	40,000	6,130
Ukraine	253,000	33,600	182,000	26,100
Venezuela	--	--	36,000	4,980
Total	2,360,000	391,000	2,520,000	390,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes the following grades of pig iron: less than or equal to 0.5 percent phosphorus content; greater than 0.5 percent phosporus content; and alloy grade. Import valuation is customs value.

Source: Bureau of the Census.

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IRON ORE

By William S. Kirk

Iron ore is essential to the economy and national security of the United States. As the basic raw material from which iron and steel is made, its supply is critical to any industrial country. Scrap is used as a supplement in steelmaking but is limited as a major feed material because the supply of high-quality scrap is limited.

Although slightly lower than that of 1995, domestic production was still higher than any other year since 1981. The domestic iron ore industry operated at close to peak capacity. Consumption and shipments were also somewhat lower than those of 1995. Internationally, the record production levels of 1995 could not be sustained.

Legislation and Government Programs

The Minnesota Department of Natural Resources (DNR) announced a reduction on the royalty rate on crude taconite used to produce pellets or concentrate that would be used as feedstock for direct reduced iron in Minnesota. The purpose of this action was to provide an incentive for construction of direct reduced facilities in Minnesota. The DNR's intent was to charge about the same royalty for a ton of DRI as is presently charged for a ton of pellets. Currently, 99% of the ore produced on the Mesabi Range is in the form of pellets. The iron content of pellets averages about 66%, compared with an iron content of more than 90% for DRI. DRI has a market value of about three times that of pellets. Royalties would be reduced by as much as one-third on taconite used to produce DRI feed for the first 3 years that a DRI plant was in operation, provided that construction began before December 31, 2000 (Skillings Mining Review, 1996c). The Minnesota DNR began the examination of the impact on ground-water quality of in-pit taconite tailings disposal.

The Western Australia State Government continued to support increased investment in further processing of iron ore through a new initiative specifically designed to encourage value adding (The TEX Report, 1996c).

The U.S. Congress passed a law to modernize the U.S. Coast Guard Icebreaker *Mackinaw*. The Coast Guard Authorization Bill of 1996 directed the Coast Guard to develop plans and a cost estimate for reengineering and other modifications that will permit the Icebreaker to continue to operate with a reduced crew while maintaining its ability to break ice around the clock when necessary (Lake Carriers Association, 1966).

Production

Domestic iron ore production reached 62.1 million metric tons. The nine taconite mining operations in Michigan and Minnesota accounted for virtually all domestic iron ore production. These were, on the Mesabi iron range in northeastern Minnesota, Eveleth Mines LLC (EVTAC Mining; formerly Eveleth Mines), Hibbing Taconite Co. (Hibbtac), Inland Steel Mining Co., LTV Steel Mining Co., National Steel Pellet Co., Northshore Mining Corp., and the US Steel Group USX (Minntac). The two on the Marquette iron range in the Upper Peninsula of Michigan were the Empire and the Tilden Mines.

U.S. production data for iron ore are developed by the U.S. Geological Survey (USGS) from two separate, voluntary surveys of domestic operations. The annual "Iron Ore" survey (1066-A) provides 100% of total production shown in tables 1 through 4. This information is supplemented by employment data, mine inspection reports, and information from consumers. The American Iron Ore Association (AIOA) provided data on ore shipments from loading docks on the upper Great Lakes, as well as receipts at transfer docks and furnace yards nationwide. The dock and steel plant data were compiled jointly by AIOA and the American Iron and Steel Institute (AISI).

Although iron ore was produced by 14 companies, 9 of them accounted for 98.7% of all domestic production. The 14 companies operated 14 mining operations, 10 concentration plants, and 10 pelletizing plants. Of the 14 mining operations, 13 were open pit and 1 was an underground operation. Virtually all ore was concentrated before shipment, and 98.4% was pelletized.

Combined U.S. and Canadian production represented about 9.6% of the world output of usable ore in 1996. The leading producer was Brazil, which accounted for 21.3% of world output in terms of metal content, followed by Australia, with 16.9%. Trends in world mine production by country, since 1992 are listed in table 17.

At 62.1 million tons, domestic iron ore production was less than 1% lower than that of 1995. Eleven mines produced ore for the iron and steel industry, while the remainder produced ore mainly for cement plants. Productivity in the Lake Superior District in terms of tons of usable ore produced per worker-hour increased as usual. An average of 3.3 tons of crude ore was mined for each ton of usable ore produced. Low-grade ores of the taconite type mined in Michigan and Minnesota accounted for 99.7% of total crude ore production. U.S. production of pellets totaled 61.1 million tons. The average iron content of usable ore produced was 63.2%.

Cleveland-Cliffs Inc. (Cliffs) announced an international joint venture to produce and market reduced iron briquettes for the steel industry. The venture's participants, through subsidiaries,

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will be Cliffs, 46.5%; LTV Corp, 46.5%; and Lurgi AG of Germany, 7%. Plans called for Cliffs to manage the project, to be located in Trinidad and Tobago, and to be responsible for sales by the venture company, Cliffs and Associates, Ltd. The plant will be designed to produce at least 0.5 million metric tons of briquettes per year. The project was to incorporate the first commercial use of the Circored fluidized bed technology developed by Lurgi Metallurgie GmbH, a member of the Lurgi Group. The iron ore fines feedstock will be supplied by Companhia Vale de Rio Doce (CVRD) of Brazil under a long-term contract. After a successful startup, Cliffs expected to increase the production capacity to 1.5 million metric tons per year) (Skillings' Mining Review, 1996b).

Michigan.—Michigan accounted for 24.3% of the output of usable ore in 1996. All the State's production was from the Empire and the Tilden Mines near Ishpeming in Marquette County and nearly all was pelletized. Both mining ventures are managed by Cleveland-Cliffs Iron, a subsidiary of Cliffs. Cliffs announced that after 16 years of being idle, the Republic Mine would be closed permanently. The Republic Mine supplied the ore for the first pellets produced in Michigan in 1956.

Minnesota.—Minnesota produced 75.1% of the national output of usable ore. All the State's production came from open-pit mines on the Mesabi Range. Production of pellets totaled 47.1 million tons.

Eveleth Mines went through a period of significant transition late in the year. First the management and ownership structures were changed after Oglebay Norton Co. announced that, as of December 31, 1996, it would not extend its contract as manager and employer of Eveleth Mines. That announcement was followed by another stating that Oglebay was selling its interest in the taconite operation that it had managed since operations were begun in 1965.

Following those changes, the operation was reorganized from Eveleth Mines to Eveleth Mines LLC (EVTAC Mining). Eveleth Mines was not a legal entity; rather it was a collective name for Eveleth Taconite Co., formed in 1965, and Eveleth Expansion Co., formed in 1976. The new company, EVTAC Mining, is 45% owned by Eveleth Taconite Co., a wholly owned subsidiary of Rouge Steel Co., Dearborn, MI; 40% owned by Virginia Horn Taconite Co., a wholly owned subsidiary of AK Steel Corp., Middletown, OH; and 15% owned by Ontario Eveleth, a wholly owned subsidiary of Stelco Inc., Hamilton, Ontario. The Thunderbird Mining Co., a wholly owned subsidiary of EVTAC Mining, has replaced Oglebay Norton Taconite Co. as the employer company at the Thunderbird Mine and the Fairlane plant

Another change is the relationship between the management of the operation and the steelmakers that own it. EVTAC is a limited liability company that is managed and operated locally and sells its product on a contract sales basis to its members as well as on the open market. That makes EVTAC the first taconite operations on the Mesabi Range to be locally managed. As part of this new relationship, EVTAC will arrange its own financing, and, unlike other iron ore operations, the company will have to deal directly with a bank or other lending institution to obtain financing.

The next part of the transition was aimed at increasing productivity at the mine and the plant. At the mine, EVTAC will buy 240-ton trucks as the 190-ton trucks are phased out. Hydraulic excavators with 25-cubic-yard-capacity buckets have been purchased. The all-hydraulic operation eliminates the need for handling large electric power cables. At the plant, production capacity will be increased through improvements to the processing facilities by the addition of centralized computer controls. Capacity is expected to increase by 10% to 5.8 million metric tons per year by 2000 at the same employment level (Skillings Mining Review, 1996a).

After National Steel Pellet Co. was closed for nearly a year in 1993 and 1994 as a result of a labor dispute, many thought the plant would not reopen. Since reopening in August 1994, however, National has become one of the lowest cost producers on the Mesabi Range and in 1996 produced its 100-millionth ton of ore. Its parent company, National Steel Corp., invested $50 million in the plant, and in 1996, National added 32 employees, for a total work force of 492. It hopes to increase annual capacity from 5.2 million tons to 5.75 million tons. The plant is in the midst of a $6 million project to increase concentrate capacity, and if a $7.5 million ported kiln project is approved, it could reach that higher production goal within a few years (Bloomquist, 1996).

The Minnesota Iron and Steel Co. (MIS), Hibbing, Minnesota, was formed to pursue the development of DRI. MIS is studying the feasibility of building a state-of-the-art taconite plant and DRI facility at the site of the Butler Taconite facility near Nashwauk, Minnesota, which closed in 1985. MIS plans to reopen mines and the tailings basin formerly operated by Butler Taconite, employing several hundred workers. Plans called for the company to sell DRI to integrated steel producers who make steel from taconite pellets and minimills who make steel from scrap. There could also be sales of pellets to the integrated steelmakers.

Missouri.—The Pea Ridge Iron Ore Co. produced iron oxide powder at its mining complex near Sullivan, Missouri. The company has the only active underground iron mine in the country. In January 1991, the company ceased pellet production and began concentrating on specialty iron oxide products, which had formerly been coproducts.

Consumption

Data on consumption and stocks of iron ore and agglomerates at iron and steel plants were provided by the AIOA. Data on consumption of iron ore for nonsteel end uses were compiled from information gathered from USGS surveys. Virtually all iron ore (98.7%) is consumed by the steel industry. Reported consumption of iron ore for manufacture of cement, heavy-medium materials, animal feed, ballast, ferrites, pigments, and other nonsteel products was 0.94 million tons.

Iron ore consumption fell from 83.1 million tons in 1995 to 79.3 million tons, a 4.6 % decrease from that of 1995. Pig iron production fell by 2.9 % and crude steel production fell by less

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than one percent. The number of blast furnaces in operation during the year ranged from 36 to 40.

Consumption of iron ore and all types of agglomerates reported to the AISI by integrated producers of iron and steel totaled 77.7 million tons. This included 64.9 million tons of pellets; 11.8 million tons of sinter, and briquettes, etc.; and 0.945 million tons of natural coarse ore. Of the ore consumed, 80% was of domestic origin, 10% came from Canada, and 10% came from other countries. Other materials consumed in sintering plants included mill scale, flue dust, limestone and dolomite, slag and slag scrap, and coke breeze. Other iron-bearing materials charged to blast furnaces included steel-furnace slag, mill scale, and slag scrap.

Prices

Most iron ore prices are negotiated between buyer and seller. About 80% of domestic ore is produced by captive mines (mines producing for company smelters) and, therefore, does not reach the open market. The average f.o.b. mine value of usable ore shipped in 1996 was $29.86 per ton, somewhat higher than that of 1995. This average value should approximate the average commercial selling price less the cost of mine-to-market transportation.

Although international iron ore producers won price increases for 1996, when adjusted for inflation, prices were much lower than those of 1990. Using Carajás and Eastern Canadian fine ores as examples, their 1996 prices were 25% lower than those of 1990. The inflation adjustment factor used was the Consumer Price Index (CPI) for Urban Consumers from the Bureau of Labor Statistics. The CPI was rebased to 1982-1984.

Transportation

Because virtually no iron ore is consumed near where it is produced, the ore must be transported, often great distances. Nearly all iron ore leaves the mine by rail, and much of it is then transferred to ships. In the United States, a much larger proportion of ore is moved by water than elsewhere because of the proximity of the mines to the Great Lakes, which offer low-cost transportation. No taconite mine is more than about 100 kilometers (60 miles) from Lake Superior or Lake Michigan, and most are much closer. From 1991 through 1996, an average of 89.7% of all ore produced was transported on the Great Lakes. Iron ore, in fact, is the mainstay of U.S.-flag Great Lakes shipping. From 1992 through 1996, iron ore constituted 47.0% of U.S.-flag cargoes, followed by limestone/gypsum at 21.6%. Including transshipments, U.S.-flag carriers moved 51.8 million tons of iron ore in 1996, an increase of 2.2% compared with that of 1995. Transshipments of iron ore occur on the way to steelworks in Cleveland, OH. These steelworks must be reached via the Cuyahoga River, which cannot accommodate vessels longer than 193 meters (635 feet) with a beam of 21 meters (68 feet). Few Great Lakes vessels are this small, so the ore carried by most lakers must be taken to nearby Lorain, OH, offloaded onto smaller vessels, and transshipped to Cleveland.

World iron ore exports were 430.8 million tons in 1996, down from 439.7 million tons the previous year. International seaborne trade fell from about 400 million tons in 1995 to about 390 million tons in 1996.

Foreign Trade

U.S. exports of iron ore were 18.9% higher than those of 1995. Virtually all exports consisted of pellets shipped via the Great Lakes to Canadian steel companies that are partners in U.S. taconite projects in Michigan and Minnesota. U.S. imports of iron ore at 18.4 million tons were 4.8% higher than those of 1995. Net imports, which averaged 11.5 million tons from 1989 through 1996, were 12.1 million tons in 1995. This was equivalent to 14.5 % of U.S. ore consumption. Canada's share of imports was 53.3 %, and Brazil's was 28.1%.

World Review

Production.—World demand eased in 1996 owing to lower crude steel production in Japan and Europe. Internationally, iron ore production fell to 1,019 million tons. Although iron mining was widespread, with production in 53 countries in 1996, a small number of countries accounted for the bulk of world production. Three countries, Australia, Brazil, and China, accounted for 56.5% of world production. In terms of gross weight, China was the largest producer, accounting for 24.5% of world production, but because of its low ore grades, was third in world iron ore production, with only 13.7 % of the total.

Consumption.—World pig iron production, the best indicator of iron ore consumption, has remained flat since 1990. Production in 1996 was virtually the same that of 1990. During this period, China, Europe, the former Soviet Union [FSU], Japan and North America have accounted for more than 80% of the world's pig iron production. In Europe, Japan and North America, pig iron production has remained virtually constant. Production fell considerably in the FSU and rose dramatically in China. Production has also increased substantially in other parts of Asia, particularly India, the Republic of Korea, and Taiwan. Asia's share of world pig iron production rose to 44.8% from 34.4% in 1990; this trend is expected to continue. Iron ore consumption in Japan, as shown by pig iron production, has been flat recently partly because of changes in the Japanese automobile industry, a major consumer of steel. Long a major consumer of iron ore, Japan produced an average of 78,625 metric tons per year of pig iron for the 5-year period from 1987 through 1991. In the next 5-year period, from 1992 through 1996, pig iron production averaged 74,032 tons per year, a decrease of almost 6% (Duisenberg, 1997). The Japanese automobile industry produced 13.5 million units in 1990, of which 3.5 million were produced overseas. In 1995, Japanese automobile production had fallen 10 million units, of which 6 million were produced overseas (The TEX Report, 1996b).

Trade.—Australia and Brazil continued to dominate the

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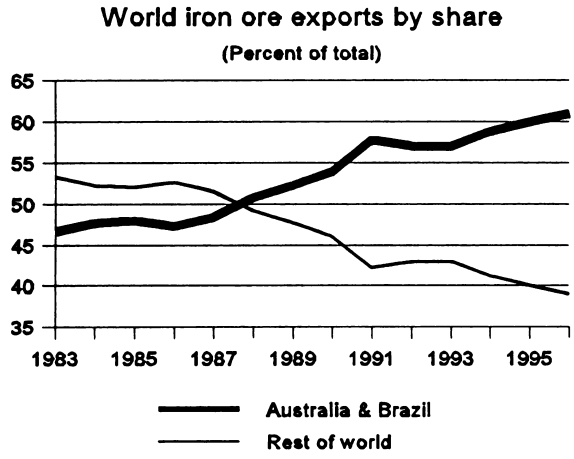
international export market, accounting for 61.0% of world exports. (See graph below.)



In 1996, 39.7 % of world iron ore production was exported, down from 42.9% in 1995. Australia was the leading exporter of iron ore, shipping 135.7 million tons to world markets, followed closely by Brazil, which exported 129.7 million tons. The next largest exporter was India, at 7.3%. Total exports were 434.9 million tons, down from 447.3 million tons in 1995. Australia's principal export customer, Japan, accounted for 44.4% of its exports, with Asia as a whole accounting for 79.7%. Brazil's primary export customers were Asia (41.0%) and Western Europe (40.0%).

Japan was, by far, the world's largest importer, accounting for 27.7% of all iron ore imports. The next largest was China, which took 10.1% of total world imports, followed by Germany at 9.1%. Australia supplied 49.9% of Japan's iron ore needs, followed by Brazil (22.4%) and India (13.3%).

Australia.—The country continued to be the world's leading exporter of ore.

BHP Iron Ore Pty. Ltd.'s Yandi expansion project (also called Yandi 2) opened in October. It involved the development of a second mining operation based on an estimated 200 million tons of ore in the Yandi Central Mesa 1 and 2 deposits. The development also includes a 10-kilometer (6-mile) rail spur which connects to the existing Yandi line. The expansion will duplicate the existing Yandi mining operation (Yandi 1), which started in 1992. Yandi 2 was principally developed to meet increased demand and will take total capacity for the mine from 15 million tons per year to 25 million tons per year and can be further expanded to 35 million tons per year if required.

BHP expects to begin developing Orebody 18 in March 1997. The deposit is located about 32 kilometers (20 miles) east of the existing Mount Whaleback operation at Newman and reportedly contains about 116 million tons of high grade ore, which the company proposes to extract at an initial rate of 5 million tons per year, increasing during the next several years to 10 million tons per year. BHP received environmental approval late in the year. The operation will be serviced by an 8-kilometer rail (5-mile) spur from the existing Jimblebar line.

BHP began construction of a 2- to 2.5-million-ton-per-year DRI/ hot briquetted iron (HBI) plant at Port Hedland, on the coast of Western Australia. The $1.125 billion facility, which includes the HBI plant, beneficiation plant, overland conveyor, and port infrastructure for Nelson Point and Finucane Island was expected to begin production in late 1998. This is the first use of the FINMET (see Current Research and Technology) technology and the first DRI plant in Australia.

In July, BHP commissioned its Newman power station, which is rated at 105 megawatts, and uses gas from the Goldfields gas pipeline, which was completed in October. This 1,380 kilometer (857 mile) pipeline provides competitive supplies of energy to the iron-ore-producing region of eastern Pilbara, in Western Australia (Western Australian Department of Resources Development, 1997).

Hamersley Iron, Australia's largest iron ore producer, loaded its 100-billionth ton of ore at the port of Dampier in Western Australia. Hamersley currently has five mines in the Pilbara region of northwestern Australia, all located within a radius of 80 kilometer (50 miles) of Mount Tom Price, its largest mine and the first to be established 30 years ago. The company is developing a new mine at Yandicoogina, 150 kilometer (93 miles) east of Tom Price. The area reportedly contains a billion-ton resource of pisolitic ore. Hamersley expects the mine to be in production in 1999, eventually producing a rate of 15 million tons per year with a 30-year life. The mine will be linked to Hamersley's existing rail and port facilities (CRA Gazette, 1996; RTZ-CRA, 1996).

Robe River shipped its 400-millionth ton of ore. The company modernized its production fleet at its Mesa J Mine near Pannawonica with the purchase of excavators, haul trucks, and rotary blasthole drill rigs.

Cleveland-Cliffs Inc. closed its Savage River Mines in Tasmania because of the depletion of economically recoverable ore (Cleveland-Cliffs Inc., 1996). Goldamere, a Brisbane-based company, trading as Australian Bulk Minerals, planned to reopen the mine in 1998 (Metal Bulletin, 1996b).

Brazil.—CVRD, the world's largest iron ore producer, led a consortium that was building a $270 million, 210-megawatt dam in east-central Minas Gerais State. The dam will allow CVRD, with a 35% interest in the consortium, to become partially self-sufficient in energy. Named Igarapava, the dam was expected to go into operation in December 1998. To help finance the project, CVRD signed an agreement with Voest Alpine Industrienlagenbau GmbH (VAI) of Linz, Austria, to swap iron ore for electricity generators for the dam. The deal called for 3.2 million metric tons of ore to be exchanged over 5 years in return for five generators worth $57 million. VAI is Austria's largest steelmaker in addition to being a major producer of hydroelectric generators. VAI's mine, which has been worked since the Middle Ages, is scheduled to close in 1997 (International Iron and Steel Institute, 1995; Kepp, 1996).

CVRD produces iron ore in two integrated mine-rail-port systems known as the Southern and Northern systems. The Carajás iron district is located in the Northern system. Ore is transported by the Carajás Railroad to the port of Ponta da

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Madeira. The Southern system includes the mines in Minas Gerais from which ore is transported by the Vitória-Minas Railroad to the port of Tubarão, where CVRD has a pelletizing complex that consists of six plants with a combined capacity of 19 million metric tons per year. The company expanded the concentration mill at its Conceição Mine in the Southern system, raising production capacity to 20 million metric ton of pellet feed (CVRD, 1996).

CVRD was building a $7 million screening plant at its Carajás complex to fulfill its contractual obligations to supply fine ore to the hot briquetted iron (HBI) plant that was to be built in Trinidad and Tobago by Cliffs and Associates, Ltd. (See Production Section.) The plant was scheduled to be producing 900,000 tons per year by February 1998. The HBI plant will have an initial capacity of at least 500,000 tons per year (American Metal Market, 1996).

Canada.—The three mining operations in the Labrador Trough area of northern Quebec and Labrador accounted for 98% of Canadian iron ore production. These were the Iron Ore Company of Canada (IOC), Quebec Cartier Mining Co. (QCM) and Wabush Mines. Canadian production, at 36 million tons, declined 4% from that of 1995 (Boyd, 1996).

India.—A newly opened railway line in the east Indian State of Orissa doubled the transport capacity for iron ore shipped from the mines at Bailadila to the Visag steel plant and port. The 164-kilometer (102-mile) railway took 9 years to complete because of the difficult terrain (Metal Bulletin, 1996c).

Essar Gujarat Ltd. began making test runs on its new 3-million-tons-per-year pellet plant in Visakhapatnam. The Lurgi type plant was completed in May 1996. Essar plans to produce 2 million tons per year for the first year and 3 million tons per year thereafter. During the first 2 years, the plant will produce pellets for the blast furnace market and will then switch to pellets for direct reduction (The TEX Report, 1996c).

The RTZ-CRA joint venture Orissa Mining Corp. formed to develop iron deposits in Orissa State received Government approval. The Gandhamardan and the Malangtoli deposits are located in the Keonjhar-Singhbum district of Orissa State. RTZ-CRA owns Hamersley Iron of Australia (Metal Bulletin, 1996a; RTZ-CRA, 1996).

Norway.—The Norwegian Parliament voted to close Sydvaranger, the world's most northerly iron mine at Bjørnevatn near Kikenes. To remain in operation, the mine would have had to convert from open-pit to underground mining, requiring further Government subsidies. The mine had been operating at a loss since the mid-1970's (Metal Bulletin, 1996d).

Spain.—Compañía Andaluza de Minas closed its iron mines at Marquesado, in Granada, in October.

Sweden.—Kiirunavaara AB (LKAB), the State-owned iron ore producer, aggressively continued its efforts to expand production, to cut costs, and to improve quality. The expansion effort resulted in decisions made to mine that part of the Kiruna main ore body that extends under Lake Luossajärvi and to develop the hematite deposits at its Malmberget Mine. Mining operations towards the north in the underground mine at Kiruna are currently restricted because of the risk of water seeping into the mine from the nearby lake. LKAB has been granted all the necessary permits for mining the Lake Ore, as it is known, and for draining the southern part of Lake Luossajärvi, which is separated from the northern part by a rail causeway. This is expected to add 4 years to the operating life of the mine.

At Malmberget, there are numerous ore bodies, most of which contain magnetite and a number of which contain hematite. When mining began, hematite, because it is virtually nonmagnetic, was too difficult and expensive to handle from a mineral processing point of view. However, with new, proven technologies, it is possible to exploit certain hematite bodies. Production is expected to be underway by May 1998. This is expected to increase production at Malmberget by 1.7 million tons per year of finished products in the form of fines and pellets, bringing the total annual production to 8.7 million tons per year.

To reduce costs, LKAB assumed control of the ore rail system and improved the harbor at Luleå, on the Gulf of Bothnia. The ore line, a 500-kilometer (310-mile) long railway, is the main artery for LKAB's ore traffic. It stretches from Luleå, to Narvik on Norway's Atlantic coast. LKAB delivered 20.6 million tons of ore products, of which 12.5 million tons was shipped via Narvik. The rest, 8.1 million tons, was delivered via Luleå. LKAB assumed control of the Norwegian part of the rail line on July 1 by acquiring 51% of the equity; the company had gained control of the Swedish part of the line some years earlier. Plans call for upgrading the railway so that it can carry heavier loads. The upgrade would raise the carload to 100 tons. Currently, railcars can carry no more than 80 tons each. This means that 8 or 9 trains a day to Narvik could carry the same cargo that requires 12 or 13 trains today.

To improve the quality of its products, LKAB decided to construct a pilot-scale blast furnace at Luleå. The pilot blast furnace is expected to reduce lead times for product development and market introduction and to result in better test methods for use in the production of pellets.

Outlook

At current consumption rates, United States iron reserves will last well into the 21st century. The domestic iron ore industry is totally dependent on the steel industry for sales. This dependence is not expected to change in the near future. Because of this relationship, the reader is referred to the outlook section in the "Iron and Steel" chapter. It is difficult for the United States to compete elsewhere in the world iron ore market because of the inland location of its mines and high labor and energy costs. Only 8.3% of the iron ore produced from 1990 through 1996 was exported; virtually all of it was pellets that went to steelworks in Ontario. For the near term, growth of the U.S. iron ore industry is tied to the growth of the integrated steelworks along the Great Lakes. The hope for the domestic iron ore industry is that one or more of the new direct reduction processes will prove to be economic for Lake producers. If this occurs, then the domestic industry can supply the rapidly expanding minimill sector of the steel industry. Electric arc

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furnaces (EAF) currently account for 42% of total crude steel production, and, by 2000, 15 million tons per year of new production capacity is expected, which will increase EAF output by 30% and raise its share of steel produced in the United States to nearly 50%.

Steel products require lower residual alloy content than can be readily achieved with scrap. This indicates a role for imported DRI in the coastal regions of the United States. The growth of gas-based DRI production capacity outside North America has been spectacular in recent years. Although a large part of this growth has occurred in Venezuela, the bulk of the construction has been spread evenly through a variety of countries that have surplus natural gas. It is too early to tell whether coal-based DRI production will be economically feasible in the United States. No matter how spectacular DRI growth is over the next decade, it will not be able to replace more than a fraction of the world's blast furnace production because of technological restrictions. The blast furnace is expected to remain the mainstay of the iron and steel industries in most developed countries during the next 25 years.

At current consumption rates, international iron reserves are sufficient to meet demand, for at least 100 years. On the basis of recent growth rates in Asia, additional iron ore production capacity will be needed. As in the United States, much of the increase in consumption of iron will be from newly constructed minimills. Unlike the United States, however, where the consumption of iron ore in blast furnaces is declining, much of the additional ore needed will go to feed blast furnaces. Since 1992, four major-sized modern blast furnaces with an 11.6-million-ton-per-year capacity have been built and six more with a 12.5-million-ton-per-year capacity are being constructed or are committed between 1997 and 2002 (Skillings Mining Review, 1996d). Because iron ore prices have not risen substantially and industry observers see no reason to believe that they soon will, it seems unlikely that future increases in supply will come from greenfield operations. Supply increases would, instead, come from low-cost brownfield expansions by existing producers in the major supplier countries, such as Australia and Brazil.

Most of the recent growth in iron ore consumption has come from Asia, particularly China, the Republic of Korea, and Taiwan.

Since 1990, Australia, Brazil, and India provided 84.8% of the ore for the primary Asian iron ore importing countries of China, Japan, Korea, and Taiwan. During this period, these importers accounted for 96.6% of total Asian imports and 48.2% of world imports. Australia's share of this export market is the largest and fastest growing. From 1990 through 1996, Australia's share was 48.6%, compared with 23.3% and 12.9% for Brazil and India, respectively. Australia's exports to the four Asian importing countries rose by 34.2% during this period, while those of Brazil increased by 9.6% and those of India fell slightly.

Current Research and Technology

A joint venture project that marked the first commercial use of the Circored fluidized bed technology began during the year. The venture's participants, through subsidiaries, were Cleveland-Cliffs Inc., 46.5%; LTV Corp, 46.5%; and Lurgi AG of Germany, 7%. The process was developed by Lurgi Metallurgie GmbH, a member of the Lurgi Group (Engineering and Mining Journal, 1996; Metal Bulletin, 1996e).

The Circored process differs from most DRI technologies in that it does not require that ore be pelletized. Instead, iron ore fines are reduced by hydrogen in a two-step process at about 600° and 60 pounds per square inch, gauge. First, 50 to 70% reduction is obtained in a circulating fluidized bed in 15 to 20 minutes, then reduction is completed in 2 to 4 hours in a bubbling fluidized bed (Chemical Engineering, 1996; New Steel, 1996). The final product contains no carbon, and the only byproduct is water. Trinidad and Tobago was chosen as the location for the plant because of its abundant supply of natural gas and proximity to a source of iron ore fines (Cleveland-Cliffs Inc, 1996).

BHP began construction of a DRI/HBI plant using FINMET technology, which involves the reduction of fine iron ore concentrate by using reformed natural gas. Test results have shown that BHP fines will work well with this process. The FINMET process is an improvement on the fluidized iron ore reduction (FIOR) process and was developed by FIOR de Venezuela and Voest Alpine Industrienlagenbau. The process uses three or four conventional bubbling fluid beds to preheat and reduce ore fines that range in size from 0.01 to 12 millimeters. The product from the process is briquetted. The reducing gas is produced by a steam reformer, and top gas is recycled from the reactors. Both gas streams are scrubbed to remove CO_2, and the combined stream is heated in a gas-fired heater before entering the reactor system. One of the major advantages claimed for the process is that it can use iron ore fines without agglomeration (BHP Minerals, 1995).

Midrex Direct Reduction Corp. and its parent company, Kobe Steel Ltd., have developed a new direct reduction process known as the spouted iron reduction (Spirex) process. The new process uses iron ore fines as feed and natural gas as the reductant to produce DRI fines, which can be hot-briquetted. The companies plan to build a demonstration-scale plant for the process near Opco, Kobe Steel's subsidiary that produces HBI. Opco, located in Puerto Ordaz in the eastern Venezuelan State of Guayana, has available land and access to natural gas and iron ore fines. The plant is expected to begin operations in the second quarter of 1998 with an annual capacity of 30,000 metric tons. An advantage of the Spirex process is that it should be able to use a wide range of iron ore fines. Turbulent movement of the fines in the preheater and the first stage reactor is supposed to degrade the iron ore particles into smaller sizes and thus make them more uniform in size.

If the process proves to be commercially feasible, then it should enable Midrex to offer its customers a wider range of options. Midrex is the leader in providing direct reduction

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technology. Its standard process, currently in use around the world, accounted for 65% of DRI production in 1995. In this process, iron ore lumps or pellets are reduced by using natural gas. Midrex and Kobe Steel are also developing the Fastmet process, which uses coal and iron ore fines to produce DRI in a rotary hearth furnace. A Fastmet demonstration plant has been operating in Japan for some time. Construction of a commercial-scale plant in Louisiana is expected to begin in the first quarter of 1997. Also, the companies earlier announced a project to develop an as-yet unnamed process that will produce liquid iron for EAF's using a self-fluxing pellet made of pulverized coal and iron ore fines.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT IRON ORE STATISTICS 1/ 2/

(Thousand metric tons and thousand dollars unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Iron ore (usable, 3/ less than 5% manganese):					
Production	55,593	55,661	58,382	62,489	62,073
Shipments	55,600	56,300	57,600	61,100	62,200
Value	$1,550,000 r/	$1,380,000 r/	$1,410,000 r/	$1,730,000 r/	$1,770,000
Average value at mines, dollars per ton	$27.90 r/	$24.50 r/	$24.50 r/	$28.40 r/	$28.50
Exports	5,060	5,060	4,980	5,270	6,260
Value	$187,000	$167,000	$163,000	$184,000	$232,000
Imports for consumption	12,500	14,100	17,500	17,600 r/	18,400
Value	$396,000	$419,000	$499,000	$491,000 r/	$556,000
Consumption (iron ore and agglomerates)	75,100	76,800	80,200	83,100	79,300
Stocks, Dec. 31:					
At mines, plants and loading docks 4/	3,780	2,500	2,790	4,240 r/	4,650
At receiving docks 5/	2,980	2,290	2,230	2,140	2,260
At consuming plants	16,100	16,500	16,300	17,100	18,800
Total 6/	22,900	21,300	21,300	23,500 r/	25,700
World: Production	924,993 r/	953,099 r/	981,403 r/	1,027,136 r/	1,020,266 e/

e/ Estimated. r/ Revised.

1/ There are four consumption numbers as shown in tables 1, 6, 7, and 8. The following explains why there is more than one consumption number and how each of them is derived. The first consumption number (79,300 thousand metric tons in 1996) appears in table 1 and is the sum of the AISI consumption number (77,700) plus reported consumption of iron ore in direct reduced iron (DRI) production and non-steel uses. The second consumption number (71,700 thousand metric tons in 1996) appears in table 6 and is the quantity of ore consumed at U.S. iron and steel plants by originating area as reported by the AIOA. The number has been converted from thousands of long tons, as it appears in the AIOA annual report, to thousands of metric tons. The third consumption number (77,700 thousand metric tons in 1996) appears in table 7 and is the quantity of ore consumed in U.S. iron and steel plants by type of ore as reported by the AISI. The number has been converted from thousand short tons, as it appears in the AISI annual report, to thousand metric tons. The fourth consumption number (73,300 thousand metric tons in 1996) appears in table 8 and is the sum of the AIOA consumption number (71,700) and two other numbers. These are quantities of ore consumed in DRI production and non-steel uses as reported to the USGS. In summary, iron ore consumption for steelmaking is reported by the AIOA and the AISI. To obtain iron ore consumption for steelmaking and other uses, iron ore consumption for other end uses must be added to AIOA and AISI reported consumption, thereby generating four consumption numbers.

2/ Data are rounded to three significant digits, except "Production"; may not add to totals shown.

3/ Direct-shipping ore, concentrates, agglomerates, and byproduct ore.

4/ Excludes byproduct ore.

5/ Transfer and/or receiving docks of Lower Lake ports.

6/ Sum of stocks at mines, consuming plants, and U.S. docks.

TABLE 2
EMPLOYMENT AT IRON ORE MINES AND BENEFICIATING PLANTS, QUANTITY AND TENOR OF ORE PRODUCED, AND AVERAGE OUTPUT PER WORKER-HOUR IN THE UNITED STATES IN 1996, BY DISTRICT AND STATE 1/

			Production (thousand metric tons)				Average per worker-hour (metric tons)		
District and State	Average number of employees	Worker-hours (thousands)	Crude ore	Usable ore	Iron contained (in usable ore)	Iron content, natural (percent)	Crude ore	Usable ore	Iron contained
Lake Superior:									
Michigan	1,890	4,040	44,800	15,100	9,310	61.8	11.10	3.73	2.30
Minnesota	5,570	8,120	162,000	46,600	29,700	63.7	20.00	5.74	3.66
Total or average	7,460	12,200	207,000	61,700	39,000	63.3	17.00	5.07	3.21
Other States 2/	93	205	533	409	233	57.1	2.60	2.00	1.14
Grand total or average	7,560	12,400	208,000	62,100	39,200	63.2	16.80	5.02	3.17

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes California, Missouri, New Mexico, South Dakota, Texas, and Utah.

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TABLE 3
CRUDE IRON ORE 1/ MINED IN THE UNITED STATES IN 1996,
BY DISTRICT, STATE, AND MINING METHOD 2/

(Thousand metric tons unless otherwise specified and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Open pit	Underground	Total quantity
Lake Superior:				
Michigan	2	44,800	--	44,800
Minnesota	8	162,000	--	162,000
Total	10	207,000	--	207,000
Other States:				
Missouri	1	--	533	533
Other 3/	6	--	--	--
Total	7	--	533	533
Grand total	17	207,000	533	208,000

1/ Excludes byproduct ore.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes California, New Mexico, South Dakota, Texas, and Utah.

TABLE 4
USABLE IRON ORE PRODUCED IN THE UNITED STATES IN 1996, BY DISTRICT,
STATE, AND TYPE OF PRODUCT 1/

(Thousand metric tons and exclusive of ore containing 5% or more manganese)

District and State	Direct shipping ore	Concentrates	Agglomerates 2/	Total quantity
Lake Superior:				
Michigan	44	--	15,000	15,100
Minnesota	420	164	46,000	46,600
Total	464	164	61,000	61,700
Other States:				
Missouri	11	243	14	269
Other 3/	140	--	--	140
Total	152	243	14	409
Grand total	616	407	61,100	62,100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data may include pellet chips and screenings.
3/ Includes California, New Mexico, South Dakota, Texas, and Utah.

TABLE 5
SHIPMENTS OF USABLE IRON ORE 1/ FROM MINES IN THE UNITED STATES IN 1996 2/

(Exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped (thousand metric tons)				Average iron content, natural (percent)	Value (thousands)
	Direct shipping ore	Concentrates	Agglomerates	Total		
Lake Superior:						
Michigan	48	--	15,000	15,100	61.8	W
Minnesota	420	2	46,300	46,700	63.7	$1,330,000
Total reportable or average	468	2	61,300	61,800	63.3	1,330,000
Other States:						
Missouri	14	263	14	291	70.5	W
Other 3/	87	--	--	87	57.1	1,590
Total reportable or average 3/	101	263	14	378	63.2	1,590
Total withheld	--	--	--	--	--	440,000
Grand total or average	570	265	61,300	62,200	63.2	1,770,000

W Withheld to avoid disclosing company proprietary data; included in "Total withheld."
1/ Includes byproduct ore.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes California, New Mexico, South Dakota, Texas, and Utah.

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TABLE 6
CONSUMPTION OF IRON ORE 1/ AT U.S. IRON AND STEEL PLANTS 2/

(Thousand metric tons)

	Iron ore originating areas					
	U.S. ores		Canadian ores			
Year	Great Lakes	Other U.S.	Great Lakes	Other Canada	Foreign ores	Total
1995	58,200	133	1,460	6,660	7,720	74,200
1996	56,800	--	2,060	5,420	7,400	71,700

1/ Excludes dust, mill scale, and other revert iron-bearing materials added to sinter.
2/ Data are rounded to three significant digits; may not add to totals shown.

Source: American Iron Ore Association.

TABLE 7
CONSUMPTION OF IRON ORE AND AGGLOMERATES AT U.S. IRON AND STEEL PLANTS, BY TYPE OF PRODUCT 1/

(Thousand metric tons)

Type of product	1995	1996
Blast furnaces:		
Direct-shipping ore	1,200	862
Pellets	67,600	64,900
Sinter 2/	12,400	11,600
Total	81,200	77,400
Steelmaking furnaces:		
Direct-shipping ore	54	83
Pellets	44	20
Sinter 2/	175	178
Total	273	281
Grand total	81,500	77,700

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes briquettes, nodules, and other.

Source: American Iron and Steel Institute.

TABLE 8
U.S. CONSUMPTION OF IRON ORE AND AGGLOMERATES, BY END USE 1/

(Thousand metric tons and exclusive of ore containing 5% ore more manganese)

Year	Blast furnaces	Steel furnaces	Sintering plants 2/	Miscella-neous 3/	Subtotal integrated iron and steel plants 4/	Direct-reduced iron for steelmaking 5/	Nonsteel end uses 6/	Total
1995	67,600	60	6,490	29	74,200	675	931	75,800
1996	64,900	87	6,670	58	71,700	684	940	73,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes dust, mill scale, and other revert iron-bearing materials.
3/ Sold to nonreporting companies or used for purposes not listed.
4/ Data from American Iron Ore Association.
5/ U.S. Geological Survey estimates based on production reports compiled by Midrex Corp.
6/ Includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighing materials, and for use in lead smelting. Data from U.S. Geological Survey surveys.

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TABLE 9
U.S. EXPORTS OF IRON ORE AND AGGLOMERATES,
BY COUNTRY OF DESTINATION 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Canada	5,260	184,000	6,240	230,000
India	1	45	(2/)	5
Mexico	(2/) r/	42	10	891
Venezuela	--	--	1	117
Other	1	50	7	719
Total	5,270	184,000	6,260	232,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 10
U.S. EXPORTS OF IRON ORE AND AGGLOMERATES, BY TYPE OF PRODUCT 1/

Type of product	1995			1996		
	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 2/ (dollars per ton)	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value 2/ (dollars per ton)
Concentrates	25	$687	$27.02	12	$430	$36.23
Coarse ores	23	414	17.97	1	39	30.36
Fine ores	51	908	17.69	34	1,070	31.81
Pellets	5,160	182,000	35.22	6,200	229,000	36.99
Briquettes	--	--	--	(3/)	14	NA
Other agglomerates	2	108	56.91	7	735	NA
Roasted pyrites	2	140	80.68	3	305	89.55
Total	5,270	184,000	34.96 4/	6,260	232,000	36.99 4/

NA Not available.
1/ Data are rounded to three significant digits, except prices; may not add to totals shown.
2/ Unit values shown are calculated from unrounded data.
3/ Less than 1/2 unit.
4/ Weighted average calculated from unrounded data by dividing total value by total tonnage.

Source: Bureau of the Census.

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TABLE 11
U.S. IMPORTS OF IRON ORE AND AGGLOMERATES, BY COUNTRY AND TYPE OF PRODUCT 1/

Country and type of product	1995 Quantity (thousand metric tons)	1995 Value (thousand dollars)	1995 Unit value 2/ (dollars per ton)	1996 Quantity (thousand metric tons)	1996 Value (thousand dollars)	1996 Unit value 2/ (dollars per ton)
Australia	570	4,150	7.28	511	3,510	6.87
Brazil	4,810	104,000	21.62	5,170	132,000	25.53
Canada	9,050	278,000	30.72	9,800	326,000	33.27
Chile	57	808	14.18	164	2,790	17.01
Mauritania	317	5,520	17.41	275	5,090	18.51
Norway	14	648	46.29	--	--	--
Peru	54	763	14.13	43	476	11.07
Sweden	47	1,710	36.38	48	2,050	42.71
Venezuela	2,500 r/	91,600 r/	36.64	2,140	78,300	36.59
Other	133 r/	3,870	29.10	238	6,220	26.13
Total	17,600 r/	491,000 r/	27.95	18,400	556,000	30.25
Concentrates	1,510	24,600 r/	16.26	1,490	26,500	17.77
Coarse ores	1,970	67,700	34.43	1,370	51,000	37.31
Fine ores	3,550	56,800	15.98	3,370	55,900	16.60
Pellets	9,390	311,000	33.17	11,400	402,000	35.28
Briquettes	54 r/	5,710 r/	105.06 r/	--	--	--
Other agglomerates	1,070	23,900	22.28	757	20,400	26.89
Roasted pyrites	12	492	41.90	10	490	50.98
Total	17,600 r/	491,000 r/	27.95 3/	18,400	556,000	30.25 3/

r/ Revised.
1/ Data are rounded to three significant digits, except prices; may not add to totals shown.
2/ Unit values shown are calculated from unrounded data.
3/ Weighted average calculated from unrounded data by dividing total value by total tonnage.

Source: Bureau of the Census.

TABLE 12
U.S. IMPORTS OF IRON ORE AND AGGLOMERATES IN 1996,
BY COUNTRY AND TYPE OF PRODUCT 1/

(Thousand metric tons)

Country of origin	Concentrates	Coarse ores	Fine ores	Pellets	Other agglomerates	Roasted pyrites	Total
Australia	--	--	511	--	--	--	511
Brazil	960	147	2,120	1,730	217	--	5,170
Canada	447	73		8,770	509	--	9,800
Chile	38	--	126	--	--	--	164
Finland	--	--	--	--	--	9	9
Mauritania	--	--	275	--	--	--	275
Norway	--	--	--	--	--	--	--
Peru	--	--	--	--	--	--	--
Sweden	48	--	--	--	--	--	48
Venezuela	--	1,150	95	899	--	--	2,140
Other	(2	1	241	--	31	1	273
Total	1,490	1,370	3,370	11,400	757	10	18,400

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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TABLE 13
AVERAGE UNIT VALUE FOR SELECTED IMPORTS OF IRON ORE AND AGGLOMERATES IN 1996

Type of product	Country of origin	Average unit value 1/ (dollars per metric ton gross weight)
Coarse ores	Venezuela	35.88
Fine ores	Brazil	17.51
Do.	Mauritania	18.52
Do.	Venezuela	28.64
Pellets	Brazil	37.87
Do.	Canada	34.47
Do.	Venezuela	38.31

1/ Weighted averages of individual Customs values.

Source: Bureau of the Census.

TABLE 14
U.S. IMPORTS OF IRON ORE AND AGGLOMERATES, BY CUSTOMS DISTRICT 1/

(Thousand metric tons and thousand dollars)

Customs district	1995		1996	
	Quantity	Value	Quantity	Value
Baltimore	4,430	103,000	4,130	101,000
Charleston	600	20,000	602	20,600
Chicago	2,890	64,800	3,200	78,900
Cleveland	1,670	53,800	802	28,100
Detroit	342	13,600 r/	1,910	71,200
Houston-Galveston	43	1,010	72	1,980
Mobile	3,720	127,000	4,080	144,000
New Orleans	1,460 r/	31,600 r/	1,340	28,100
Philadelphia	2,390	76,100	2,180	79,400
Other	14	235 r/	83	2,310
Total	17,600 r/	491,000 r/	18,400	556,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 15
U.S. IMPORTS OF PELLETS, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Brazil	1,180	40,200	1,730	65,500
Canada	7,200	238,000	8,770	302,000
Peru	36	507	--	--
Venezuela	911	31,400	899	34,400
Other	58 r/	1,660 r/	--	--
Total	9,390	311,000	11,400	402,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 16
SELECTED PRICES FOR IRON ORE IN THE JAPANESE MARKET

(F.o.b. shipping port basis. U.S. cents per dry long ton of iron unless otherwise specified)

	Ore type	April 1 - March 31 Fiscal year 1995	Fiscal year 1996
Australia:			
Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd.	Lump ore	35.89	37.68
Do.	Fines	27.15	28.78
Robe River Iron Associates	do.	21.90	23.53
Savage River Mines Ltd.	Pellets	44.42	47.37
Brazil:			
Cia. Nipo-Brasileira de Pelotizacao (Nibrasco)	do.	46.93	50.05
Cia. Vale do Rio Doce (Carajas)	Fines	24.84	26.30
Do.	Lump ore	(1/)	(1/)
Cia. Vale do Rio Doce (Itabira)	do.	26.73	28.07
Do.	Fines	24.34	25.80
Mineracoes Brasileiras Reunidas S.A.	do.	26.14	27.45
Do.	do.	24.81	26.30
Samarco Mineracâo S.A.	Pellet feed	20.45	21.67
Canada: Iron Ore Co. of Canada (Carol Lake)	Concentrates	23.60	25.02
Chile:			
Minera del Pacifico S.A. (El Algarrobo)	Pellets	43.75	46.65
Minera del Pacifico S.A. (El Romeral)	Fines	18.85	19.98
India:			
Minerals and Metals Trading Corp. (Bailadila)	Lump ore	34.60	36.33
Do.	Fines	26.07	27.63
South Africa 2/:			
South African Iron and Steel Industrial Corp. Ltd.	Lump ore	28.74	30.50
Do.	Fines	20.65	21.89

1/ No quotation published.
2/ Price per dry metric ton unit.

Source: Trust Fund Project on Iron Ore Information, Iron Ore 1995.

TABLE 17
IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

	Gross weight 3/					Metal content 4/				
Country 2/	1992	1993	1994	1995	1996 e/	1992	1993	1994	1995	1996 e/
Albania e/ 5/	200 6/	150	--	--	--	88	85	--	--	--
Algeria	2,523	2,311	2,047	2,000 e/	1,900	1,250 e/	1,250 e/	1,000 e/	1,000 e/	1,000
Argentina	5 r/ e/	3 r/ e/	42 r/ e/	-- r/	--	3 r/	2 r/	28	-- r/	--
Australia	112,101	120,534	128,493	142,936 r/	147,100 6/	69,761	74,767	80,900 e/	88,653	93,000 6/
Austria	1,627	1,435	1,655	2,116 e/	2,100	515	452	520 e/	660 e/	600
Azerbaijan	400	300 e/	200 e/	150 e/	150	220	165	110 e/	83 e/	83
Bolivia	55	51	3	-- e/	--	35	32	2	-- e/	--
Bosnia and Herzegovina e/	500	250	200	150	150	150	100	70	52	50
Brazil	146,447	150,000	167,900	177,000 r/	180,000	95,200	98,000	108,800	115,050 r/	117,000
Bulgaria	800 e/	880	466 r/	469 r/	770 6/	239	264 r/	140 r/	141 r/	231
Canada 8/	33,167	31,830	37,703	36,628 r/	36,030 p/	21,183	19,990	24,235	23,416 r/	23,034
Chile	7,643	7,010	8,341	8,174	8,100	5,120 r/	4,390	5,223	5,119	5,000
China e/	197,600	234,660	240,200	249,350	249,550	59,300	70,400	72,050	75,000	75,000
Colombia	674	546	610	734	550 6/	350	283	317	382 e/	286
Czechoslovakia 9/	1,414	XX	XX	XX	XX	412	XX	XX	XX	XX
Egypt	2,287	2,229	3,870	3,500 r/	3,000	1,260	1,250 e/	2,100 e/	2,000 r/ e/	1,700
France	5,707	3,520	2,418 r/	1,496 r/	1,200	1,697	1,055	706	432 r/	348
Germany	109	146	146	125 r/	100	15	23	21	18 r/	15
Greece e/ 5/	1,500	1,416	1,990 r/	1,970 r/	1,990	610	575	810 r/	800 r/	810
Guatemala e/	1 6/	3	3	3	3	1 6/	2	2	2	2
India	54,870	57,375	60,473 r/	66,751 r/	67,000	35,117	36,720	37,368	42,720 r/ e/	42,960
Indonesia	288	341	335	340 e/	335	145	198	194 e/	197 e/	194
Iran 10/	5,647	9,870	8,690	9,080	9,000	3,000 e/	4,800 e/	4,300 e/	4,500 e/	4,500
Japan	40	11	3	3	3 6/	25	6	1	1	1 6/
Kazakstan	17,300	13,000	10,400	14,900	12,600	9,500	7,200 e/	5,700 e/	8,200 e/	6,900
Korea, North e/	10,500	10,500	11,000	11,000	11,000	4,900	4,900	4,900	5,100	5,100
Korea, Republic of	222	219	191	184 r/	221 6/	134	122	107	103 r/	124 6/
Liberia e/	1,742 6/	--	--	--	--	1,000 6/	--	--	--	--
Macedonia e/	20	20	20	20	20	6	6	6	6	6
Malaysia	320	246	243	202	325 6/	195	150	148	123	208 6/
Mauritania	8,202	9,360	11,440 r/	11,330 r/	11,400	5,330 e/	5,900 e/	7,000 e/	7,000 e/	7,000
Mexico 11/	10,964	11,435	8,538	7,065 r/	7,794 6/	7,127	7,433	5,516	5,625 r/	6,109 6/

See footnotes at end of table.

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TABLE 17--Continued
IRON ORE, IRON ORE CONCENTRATES, AND IRON ORE AGGLOMERATES: WORLD PRODUCTION, BY COUNTRY 1/

(Thousand metric tons)

Country 2/	Gross weight 3/					Metal content 4/				
	1992	1993	1994	1995	1996 e/	1992	1993	1994	1995	1996 e/
Morocco	83	66	65	45 r/ e/	45	51	41 e/	41 e/	30 r/ e/	30
New Zealand 12/	2,934	2,389	2,080 r/	2,362 r/	2,400	1,300 e/	1,300 e/	600 e/	900 e/	900
Nigeria e/	400	400	300	200	200	200	200	150	100	100
Norway	2,258 r/	2,162	2,364	2,012 r/	2,000	1,403	1,360	1,532	1,348 r/	1,340
Peru	2,850	4,930	7,430	6,235 r/	4,304 6/	1,845	3,205	4,830	3,968 r/	2,876 6/
Portugal 13/	15	16 e/	14 r/	15 r/	15	5	6	5	5 r/	6
Romania	1,250	904	951 e/	570 r/ e/	670	180	130	198	147 r/	175 6/
Russia	82,100	76,100	73,300	75,900 r/	69,600	45,000	41,900 r/	40,200 r/	41,700 r/	38,300
Serbia and Montenegro	551	106	32 e/	116 r/	115	176	34	10 e/	37 r/	37
Slovakia e/ 14/	XX	920	870 r/	820 r/	850 6/	XX	250	230 r/	225 r/	240
South Africa 15/	28,226	29,385	30,489	31,946	30,830 6/	18,347	19,100 e/	18,903	19,806	19,115
Spain 16/	2,967	2,475	2,082 r/	2,307 r/	2,300	1,334	1,109	992 r/	1,073 r/	1,070
Sweden	19,277	18,728	19,663	19,058 r/	20,273 6/	9,785	11,901	12,587	12,211 r/	12,975
Thailand	427	209	143	34	50	235	115 e/	78 e/	17 e/	22
Tunisia	291	299	240	225 e/	239	151 e/	153 e/	129	128	130 6/
Turkey	5,917	6,480	5,755	4,931 r/	5,000	3,200 e/	3,324 e/	3,148 e/	2,754 r/	2,800
Ukraine	75,700	65,000 e/	51,300 r/	50,400 r/	48,000	42,000	36,000 r/	28,200 r/	27,700 r/	26,400
United Kingdom	31	1	1	1	1 6/	7	(7/) r/	(7/) r/	(7/)	(7/)
United States	55,593	55,661	58,382	62,489	62,073 6/	35,251	35,245	36,762	39,577	39,243 6/
Venezuela	18,070	16,841	18,318	19,484	18,480 p/	11,807	11,010	11,980	12,743 e/	12,089
Zimbabwe	1,179	375	4	311	430	710 e/	225 e/	3 e/	160 e/	222
Total	924,993 r/	953,099 r/	981,403 r/	1,027,136 r/	1,020,266	496,875 r/	507,127 r/	522,853 r/	551,014 r/	549,328

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ Table includes data available through July 16, 1997.

2/ In addition to the countries listed, Cuba and Vietnam may also produce iron ore, but definitive information on output levels, if any, is not available.

3/ Insofar as availability of sources permit, gross weight data in this table represent the nonduplicative sum of marketable direct-shipping iron ores, iron ore concentrates, and iron ore agglomerates produced by each of the listed countries. Concentrates and agglomerates produced from imported iron ores have been excluded under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

4/ Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron content reported, except for the following countries for which grades are U.S. Geological Survey estimates: Albania, Azerbaijan, Kazakstan, North Korea, and Ukraine.

5/ Nickeliferous iron ore.

6/ Reported figure.

7/ Less than 500 tons.

8/ Series represent gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.

9/ Dissolved Dec. 31, 1992.

10/ Data are for year beginning Mar. 21 of that stated.

11/ Gross weight calculated from reported iron content based on grade of 66% Fe.

12/ Concentrates from titaniferous magnetite beach sands.

13/ Includes manganiferous iron ore.

14/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

15/ Includes magnetite ore as follows, in thousand metric tons: 1992--4,650; 1993--4,340; 1994--3,460; 1995--2,325; and 1996--2,070.

16/ Includes byproduct ore.

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TABLE 18
IRON ORE: WORLD PELLETIZING CAPACITY,
BY CONTINENT AND COUNTRY IN 1996

	Rated capacity (million metric tons, gross weight)
North America:	
Canada	25.4
Mexico	13.2
United States	67.2
Total	105.8
South America:	
Argentina	2.0
Brazil	30.1
Chile	4.2
Peru	3.4
Venezuela	9.9
Total	49.6
Europe:	
Belgium-Luxembourg	.8
Netherlands	3.8
Norway	3.2
Sweden	15.9
Turkey	1.3
Former Soviet Union	80.0
Total	104.2
Africa:	
Liberia	3.0
Morocco	.8
Nigeria	1.4
South Africa	.6
Total	4.4
Asia:	
Bahrain	4.0
China	4.5
India	11.4
Iran	2.5
Japan	4.4
Total	26.8
Oceania: Australia	4.0
World total	294.8

Sources: International Iron and Steel Institute, Brussels, Belgium; United Nations Commission on Trade and Development; Trust Fund Project on Iron Ore Information; U.S. Geological Survey.

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IRON OXIDE PIGMENTS

By Michael J. Potter

Iron oxide materials yield pigments that are nontoxic, nonbleeding, relatively inert, weather resistant, and light fast. Natural iron oxides include a combination of one or more ferrous or ferric oxides and impurities such as manganese, clay, or organics. Synthetic iron oxides can be produced in various ways, including: thermal decomposition of iron salts such as ferrous sulfate to produce reds; precipitation to produce yellows, reds, browns, and blacks (e.g., the Penniman-Zoph process); and reduction of organic compounds by iron (e.g., nitrobenzene reduced to aniline in the presence of particular chemicals) (Harben, 1995, p. 85).

Production

U.S. sold or used crude iron oxide pigment (IOP) materials were 44,700 metric tons, or 14% less than in 1995, according to the U.S. Geological Survey (USGS). Shipments of finished natural IOP were 74,100 tons, or about the same as in 1995. Output of finished synthetic IOP sold by processors in the United States was 88,400 tons, or 16% higher than in 1995.

Sold-or-used data for crude IOP material were developed by the USGS by means of a voluntary survey. Data were obtained from all six known companies, representing a 100% response rate. In a second voluntary survey, data were received from all 17 known operations, or 100%, which produced finished IOP.

Pea Ridge Iron Co. was expanding production at its plant near Sullivan, MO. Pea Ridge makes iron oxides for ferrite, pigment, densification and other markets (Chemical Marketing Reporter, 1996b, p. 20). Bayer Corp. acquired the iron oxide business of Landers Segal Color Inc., Passaic, NJ. Included were blending, marketing and distribution operations for synthetic and natural iron oxide products (Concrete Products, 1996, p. 12). Harcros Pigments Inc. received ISO 9002 certification at its plants in Easton, PA; East St. Louis, IL; and Fairview Heights, IL (Chemical Marketing Reporter, 1996c, p. 31).

A subcategory of synthetic iron oxide is regenerated iron oxide. This is a material which has been recovered from a steel industry waste product, pickle liquor, which itself comes from rust removal of steel. Traditionally, pickle liquor has either been disposed of by deepwelling or recycled into ferric chloride or regenerated. U.S. Environmental Protection Agency regulations aimed at deepwelling have led to more steel companies making arrangements with third party acid regenerators (Chemical Marketing Reporter, 1996a, p. 3). Bailey Engineers Inc. and PVS Chemicals Inc. formed a company, Bailey-PVS Oxides LLC, which will own and operate regeneration facilities. The new company initially will run Bailey's existing regeneration operation at USX Corp.'s steel plant in Fairfield, AL. Bailey-PVS also signed a worldwide cooperation agreement with the Ruthner division of Andritz, a Vienna, Austria, regeneration company. Andritz will supply technology, engineering support and equipment for all new acid regeneration plants built by Bailey-PVS (Chemical Marketing Reporter, 1996b, p. 20).

Prices

Yearend 1996 prices from Chemical Market Reporter, converted to dollars per kilogram, in bags, per truckload, f.o.b. warehouse, were black, synthetic—$1.80 to $1.94; brown, synthetic—$1.83 to $1.94; red, natural—$0.65 to $1.10; ochre, natural—$0.81; and yellow, synthetic—$1.76 to $1.89.

Foreign Trade

Because of a change in code numbers in some iron oxide trade data categories, the total of "other grade" exports for 1996 in table 5 is believed to be at least 84,000 tons with a value of $102 million instead of 27,200 tons with a value of $41.7 million.

World Review

Brazil.—Sherwin-Williams Co. and Bayer SA, the Brazilian subsidiary of Bayer AG, jointly acquired Globo SA Tintas e Pigmentos of Sao Paulo from Reckitt & Colman PLC and other shareholders for $93.5 million. Globo's annual sales were $85 million. Sherwin-Williams was to take over Globo's paint business, and Bayer was to take the synthetic iron oxide pigment business with a capacity of about 15,000 tons per year (Chemical and Engineering News, 1996, p. 18).

Canada.—A paper described the use of specular hematite (micaceous iron oxide) as a blast cleaning abrasive, especially for the surface preparation of steel, prior to coating. Specular hematite is supplied from Quebec Cartier Mining Co.'s deposit in northern Quebec. Processed concentrate is shipped to various locations, including Barnes Environmental International, Waterdown, Ontario, and other licensees of Crystalgrit Inc., Montreal, Quebec. The paper included comparison data of specular hematite, which is recyclable, with other recyclable and nonrecyclable abrasives such as silica, coal slag, garnet, staurolite, etc. After use, the spent specular hematite can be supplied to the cement industry as a source of iron for the production of portland cement. It can also be provided to sintering plants which supply iron oxide in the form of pellets or briquettes for the production of blast furnace iron (Hunt, 1996, p. 19).

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China.—There has been a long history of developing hard ferrite magnetic materials in China, according to a paper given at "China Magnetic Materials Conference" in Beijing. Hard ferrite factories are scattered widely around the country and labor costs are said to be fairly low. Because mill scale or refined pulverized iron ore is used as raw material, most hard ferrites are not of a high grade. About 60% of the hard ferrites was being used for loud speakers and 20% for electric motors. Substantial effort was being put into improving process and quality control toward increasing the output of high grade ferrites (Interaction, 1996, p. 2-3).

Outlook

The three largest Western iron oxide producers, Bayer, Harcros, and Laporte, have been active during the past few years in acquisitions, expanding capacity and undertaking joint ventures. Bayer and Laporte were focusing on granulated pigments that ease handling while reducing dusting. Harcros was focusing on surface-coated iron oxides that significantly reduce mixing and preparation times. Each of these producers announced a Chinese project: Laporte's joint venture in Fuyang, Huangdong Province was already exporting; Bayer Shanghai Pigments 20,000-ton-per-year plant was due on-stream in the second half of 1996; and Harcros was in the early stages of building a plant in Shenzen, Quangdong Province.

There have been increased Chinese exports in an already full market. One Chinese exporter estimated that Chinese material can run as low as $550 per metric ton, f.o.b. China, compared with $1,600 per metric ton for some U.S.-made material. This exporter estimated Chinese iron oxide pigment exports to be 85,000 to 100,000 tons per year. According to one U.S. company source, Chinese pigments were gaining especially in the low-value construction product markets, but had not penetrated the coatings or plastics markets (Fattah, 1996, p. 23).

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TABLE 1
SALIENT U.S. IRON OXIDE PIGMENTS STATISTICS 1/

(Metric tons, unless otherwise noted)

		1992	1993	1994	1995	1996
Mine production		W	W	W	W	W
Crude pigments sold or used		39,300	35,800	46,400	51,700	44,700
Value	thousands	$4,670	$5,020	$6,010	$6,720	$6,990
Finished pigments sold		121,000	126,000	139,000	151,000 r/	162,000
Value	thousands	$136,000	$140,000	$143,000	$160,000 r/	$183,000
Exports		21,100	22,400	21,300	17,500	16,000
Value	thousands	$32,200	$32,000	$30,700	$24,900	$23,200
Imports for consumption		45,100	43,600	51,400	59,300	62,600
Value	thousands	$49,900	$57,300	$61,400	$77,600	$74,000

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.

TABLE 2
FINISHED IRON OXIDE PIGMENTS SOLD BY PROCESSORS IN THE UNITED STATES, BY KIND 1/

	1995		1996	
Kind	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Natural:				
Black: Magnetite	13,200 r/	$2,330 r/	12,700	$2,140
Brown: Iron oxide	W	W	--	--
Umbers:				
Burnt	1,740 r/	2,640 r/	W	W
Raw	W	W	W	W
Red:				
Iron oxide 2/	49,300	9,600	49,100	9,640
Sienna, burnt	W	W	W	W
Yellow:				
Ocher	W	W	W	W
Sienna, raw	W	W	W	W
Undistributed	10,300 r/	6,510 r/	12,200	9,680
Total	74,500 r/	21,100 r/	74,100	21,500
Synthetic:				
Black: Iron oxide	18,700 r/	32,100 r/	21,000	37,800
Brown: Iron oxide	W	W	7,700	14,700
Red: Iron oxide	W	W	W	W
Yellow: Iron oxide	20,100 r/	35,300 r/	23,600	42,400
Mixtures of natural and synthetic:				
Iron oxides	W	W	W	W
Other: Specialty oxides	W	W	W	W
Undistributed	37,400 r/	71,100 r/	36,100	66,500
Total	76,200 r/	138,000 r/	88,400	161,000
Grand total	151,000 r/	160,000 r/	162,000	183,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 3
PRODUCERS OF IRON OXIDE PIGMENTS, REGENERATOR IRON OXIDES, AND STEEL-PLANT WASTE IRON OXIDES IN THE UNITED STATES IN 1996

Producers	Plant location
Finished pigments:	
Alabama Pigments Co.	Greenpond, AL
Bayer Corp.	New Martinsville, WV
Blue Ridge Talc Co., Inc.	Henry, VA
Dynamic Color Solutions, Inc.	Milwaukee, WI
Harcros Pigments Inc.	Emeryville, CA; East St. Louis, IL; Easton, PA
Hilton-Davis Co.	Newark, NJ
Hoover Color Corp.	Hiwassee, VA
Mapico, Inc.	St. Louis, MO
New Riverside Ochre Co., Inc.	Cartersville, GA
Pea Ridge Iron Ore Co.	Sullivan, MO
Prince Manufacturing Co.	Quincy, IL and Bowmanstown, PA
Rockwood Pigments	Beltsville, MD
Solomon Grind-Chem Services Inc.	Springfield, IL
Swansea Minerals Inc.	Tempe, AZ
Crude pigments:	
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer plant (closed July 31, 1979; shipping from stockpile.)	Negaunee, MI
Hoover Color Corp.	Hiwassee, VA
New Riverside Ochre Co., Inc.	Cartersville, GA
Pea Ridge Iron Ore Co.	Sullivan, MO
Swansea Minerals Inc.	Tempe, AZ
Virginia Earth Pigments Co.	Hillsville, VA
Regenerator and steel plant waste iron oxides:	
Bailey Engineers, Inc.	Fairfield, AL
International Steel Services	Allenport, PA
Weirton Steel Corp.	Weirton, WV

TABLE 4
ESTIMATED IRON OXIDE PIGMENT CONSUMPTION, BY END USE, AS A PERCENTAGE OF REPORTED SHIPMENTS

	All iron oxides		Natural iron oxides		Synthetic iron oxides	
End use	1995	1996	1995	1996	1995	1996
Coatings (industrial finishes, trade sales: lacquers, paints, varnishes)	20	22	13 r/	13	26 r/	30
Construction materials (cement, mortar, preformed concrete, roofing granules)	W	31	18	20	W	39
Colorants for ceramics, glass, paper, plastics, rubber, textiles	W	W	W	W	13 r/	9
Foundry sands	8 r/	8	16	16	--	--
Industrial chemicals (such as catalysts)	9	9	W	W	W	W
Ferrites	W	W	W	W	W	W
Animal feed and fertilizers	W	W	W	W	W	2
Other (also includes cosmetics, magnetic ink and toner, and polishing agents)	63 r/	30	53 r/	51	61 r/	20
Total	100	100	100	100	100	100

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

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TABLE 5
U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY 1/

	1995				1996			
	Pigment grade		Other grade		Pigment grade		Other grade	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	--	--	581	$380	(2/)	$3	785	$493
Australia	179	$229	1,030	2,090	34	126	544	1,370
Austria	--	--	1,950	4,930	19	19	20	25
Belgium	167	497	758	800	289	529	95	193
Brazil	143	687	13,500	5,820	15	108	175	340
Canada	246	230	102,000	20,800	19	15	10,700	13,400
Ecuador	--	--	1,860	456	16	39	1	4
Germany	366	417	1,030	4,190	288	1,220	263	983
Hong Kong	829	2,450	932	477	1,040	2,780	70	197
Indonesia	919	1,570	81	135	808	1,380	88	60
Italy	23	66	392	1,130	1	4	231	476
Japan	3,020	3,070	7,700	28,000	4,030	3,390	2,850	4,080
Korea, Republic of	2,630	6,590	2,080	6,710	989	3,830	1,300	4,280
Malaysia	763	820	239	274	42	182	155	236
Mexico	3,750	873	5,450	6,630	4,950	1,560	1,700	4,020
Netherlands	310	696	4,040	5,830	78	309	1,340	2,210
Singapore	59	15	2,180	2,770	1	3	881	1,660
South Africa	1,220	2,020	359	468	828	1,210	70	83
Spain	--	--	40	92	55	113	39	84
Taiwan	58	49	1,750	2,520	3	8	746	702
Thailand	515	805	421	760	313	570	274	547
Trinidad and Tobago	--	--	682	25	--	--	--	--
United Kingdom	521	1,500	1,760	3,430	607	2,080	2,250	3,890
Venezuela	823	267	1,840	1,640	1	4	407	57
Other	1,000	2,110	6,640	7,390	1,540	3,760	2,180	2,300
Total	17,500	24,900	159,000	108,000	16,000	23,200	27,200	41,700

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF SELECTED IRON OXIDE PIGMENTS, BY TYPE 1/

	1995		1996		
Type	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Source, 1996 (metric tons)
Natural:					
Earth colors 2/	382	$258	3,060	$1,200	Cyprus 2,560; Germany 205; Spain 179; India 60; Italy 20; United Kingdom 20; France 18; South Africa 4; Japan 1; Taiwan (3/); Poland (3/); Denmark (3/).
Micaceous	3,240	1,250	6,330	2,170	Canada 3,940; Netherlands 2,010; United Kingdom 187; France 130; Austria 38; Japan 21; South Africa 5; Mexico 4.
Umber	3,020	957	--	--	
Vandyke brown	165	183	--	--	
Total	6,800	2,650	9,390	3,370	
Synthetic:					
Black	11,000	30,700	8,780	25,600	Japan 3,910; India 2,460; Germany 1,410; Italy 370; Mexico 352; China 243; Hong Kong 18; Netherlands 10; Belgium 5; Canada 3; United Kingdom 1; France (3/).
Red	21,800	20,900	24,200	22,200	China 11,400; Canada 4,890; Germany 4,760; Japan 1,060; Spain 602; Mexico 440; Hong Kong 382; Brazil 367; Italy 98; United Kingdom 81; Belgium 49; Philippines 2; Switzerland 1; France 1.
Yellow	14,700	15,900	15,800	16,100	China 4,800; Germany 4,290; United Kingdom 2,840; Brazil 1,230; Italy 945; Mexico 732; Hong Kong 419; Spain 370; Japan 71; Belgium 30; India 20; Hungary 17; Canada 11; Switzerland 2; France 1.
Other 4/	4,950	7,500	4,410	6,670	Germany 1,750; Canada 1,350; India 539; Japan 469; Sweden 175; China 79; Mexico 34; Belgium 15; United Kingdom 4; Italy 3.
Total	52,500	75,000	53,200	70,600	
Grand total	59,300	77,600	62,600	74,000	

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes those earth colors not elsewhere specified or included.
3/ Less than 1/2 unit.
4/ Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF IRON OXIDE AND IRON HYDROXIDE PIGMENTS, BY COUNTRY 1/

	Natural				Synthetic			
	1995		1996		1995		1996	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Austria	72	$106	38	$47	--	--	--	--
Belgium	--	--	--	--	34	$638	99	$439
Brazil	--	--	--	--	1,210	1,170	1,600	1,570
Canada	946	145	3,940	511	6,380	1,560	6,260	1,510
China	--	--	--	--	12,900	7,710	16,600	10,700
Cyprus	2,960	894	2,560	768	--	--	--	--
France	2,160	795	148	149	42	64	2	60
Germany	203	237	206	259	14,100	22,400	12,200	19,900
Hong Kong	--	--	--	--	747	559	820	644
Hungary	--	--	--	--	--	--	17	28
India	--	--	60	14	1,190	734	3,020	2,380
Italy	--	--	20	6	826	1,050	1,420	1,640
Japan	6	148	22	98	8,270	33,900	5,510	26,500
Mexico	2	13	4	30	1,380	1,120	1,560	1,370
Netherlands	342	185	2,010	1,190	68	92	10	78
Spain	34	16	179	77	840	666	972	719
Sweden	--	--	--	--	360	94	175	58
United Kingdom	80	87	207	179	3,170	2,830	2,920	2,920
Other	(2/)	19	9	38	1,030	301	4	88
Total	6,800	2,650	9,390	3,370	52,500	75,000	53,200	70,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 8
NATURAL IRON OXIDE PIGMENTS: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina (ocher)	40	28	35 e/	30 e/	30
Austria	9,475	8,398	8,000 e/	8,000 e/	7,500
Bosnia and Herzegovina e/	200	--	--	--	--
Brazil e/	5,500	5,500	5,500	5,500	5,500
Chile	22,945	7,106	3,283	3,000 e/	3,000
Cyprus (umber)	5,000	6,000	9,000	9,000 e/	9,000
France e/	12,000	1,000	1,000	1,000	1,000
Germany 4/	10,100	7,712	7,475	7,500 e/	7,500
India (ocher)	142,478	138,210	170,761 r/	234,098 r/	225,000
Iran e/	2,307 5/	2,500	2,500	2,500	2,500
Italy e/	700	700	600	600	500
Pakistan (ocher)	5,126	6,196	6,000 e/	6,000 e/	6,100
Paraguay (ocher) e/	330	330	330	300 r/ e/	300
South Africa	1,114	1,186	2,084 r/	5,256	643 5/
Spain: e/					
Ocher	8,200	8,000	7,000	8,000	7,000
Red iron oxide	18,000	16,000	15,000	16,000	15,000
United States	W	W	W	W	W
Zimbabwe	538	390	438	585 r/	600

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Estimated data are rounded to three significant digits.
2/ Table includes data available through June 4, 1997.
3/ In addition to the countries listed, a considerable number of others undoubtedly produce iron oxide pigments, but output is not reported and no basis is available for formulating estimates of output levels. Such countries include, but are not limited to, Azerbaijan, China, Kazakstan, Russia, and Ukraine. Because unreported output is probably substantial, this table is not summed to provide a world total.
4/ Includes Vandyke brown.
5/ Reported figure.

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KYANITE AND RELATED MATERIALS

By Michael J. Potter

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that have the same chemical formula, $Al_2O_3 \cdot SiO_2$, but differ in crystal structure and physical properties. When calcined at high temperatures, these minerals are converted to mullite, $3Al_2O_3 \cdot {}_2SiO_2$, and silica, SiO_2, which are refractory materials. Andalusite and sillimanite are not produced in the United States, except for a pyrophyllite/andalusite/sericite deposit that is mined by Piedmont Minerals Co., Inc., near Hillsborough, NC. In processing the ore, andalusite is not separated but remains in various combinations with the pyrophyllite and sericite to produce blends of products. Some examples of end-uses of the company's products include refractories; whitewares, such as tile and sanitaryware; and structural ceramics, including earthenware and stoneware. South Africa and France are the main producing countries of andalusite. India has been the largest producing country of sillimanite with an estimated 10,000 metric tons in 1996. *(See table 4.)*

Iron and steelmaking is the largest end use for refractories in general. "Clean steelmaking" is said to put increasing demands on refractories. "Clean steel" contains low amounts of oxide and sulfide impurities, nitrogen, hydrogen, and carbon. The production of "clean steel" is now commonly done by ladle metallurgy. In the past, ladles, which have refractory linings, were mainly used for transport of molten steel, but increasingly, they are secondary metallurgical reactors. Originally, the main function of the ladle refractory lining was to minimize temperature loss, but now it must resist increased chemical attack (Semler, 1996, p. 37).

Production

Kyanite was mined at two open-pit locations by Kyanite Mining Corp. in Buckingham County, VA. The company also operated beneficiation plants and calcining facilities for conversion of kyanite to mullite. High-temperature sintered synthetic mullite was produced by C-E Minerals at Americus, GA, and North American Refractories Co. at Greenup, KY. Data were obtained for the kyanite and both synthetic mullite producers but cannot be published because of their proprietary nature.

Consumption

The U.S. Geological Survey does not collect data on end uses of kyanite and synthetic mullite. However, refractories were a major end use, including monolithics such as ramming mixtures, castables, gunning mixes, and plastics. Some other end uses were whitewares, kiln furniture, acoustical tiles, catalytics, electrical insulators, shell castings, foundry uses, and investment casting procedures.

Foreign Trade

Shipments of U.S. kyanite, mullite, and synthetic mullite were made to worldwide locations including Europe, Latin America, the Pacific Rim, and other countries. In recent years, imports of andalusite have been largely from South Africa. There were no known U.S. imports of kyanite or sillimanite in 1996.

World Review

Capacity.—Because actual capacity data were generally not available, the data in table 3 are estimated for marketable product at yearend 1996. For most countries, capacity was considered to be the same as the highest production during the past 5 years.

China.—The Henan Xixia Andalusite Mine in Henan Province, China, was believed to be constructing a new processing plant. The capacity would be about 200,000 tons per year of ore, yielding about 10,000 tons per year of andalusite product. The other Chinese producer, Shandong Wulian Andalusite Mine, in Shandong Province, was producing about 3,000 tons per year. Chinese material was said to have a higher iron content than South African material (Skillen, 1996, p. 63-64).

South Africa.—Anglovaal Minerals announced plans to reopen its mothballed Havercroft andalusite mine in Northern Province. Capital costs of reestablishing the mine and upgrading the processing plant were estimated to be $9.4 million. Production was projected to restart in the second quarter of 1997. Annual production capacity was planned to be about 60,000 tons, and the bulk of the output was slated for export to refractories manufacturers worldwide. Production from Havercroft would supplement Anglovaal's existing andalusite production from its Rhino Andalusite Mines Ltd. subsidiary near Thabazimbi, also in Northern Province. The Rhino Mine was producing about 120,000 tons per year, about half of which was being exported (Industrial Minerals, 1996, p. 16).

The other South African producers of andalusite were Samrec Pty. Ltd., a wholly owned subsidiary of French refractory clay and andalusite producer Damrec, and Hoogenoeg Andalusite Pty. Ltd. Samrec was operating three mines in South Africa with a total capacity of 125,000 tons per year. Hoogenoeg, with a capacity of 36,000 tons per year, was havingk its assets purchased by Hernic Exploration Pty. Ltd.

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(McCracken and Kendall, 1996, p. 53-54).

Outlook

Monolithic refractories were being used in a growing number of ways especially because of the availability of advanced castables, self-flow castables, improved gunning materials, and other developments. However, according to one refractories consultant, the total U.S. market value of all refractories may decline from 2% to 9% by the year 2000 as continuous improvement and longer life of refractories result in lower growth of sales and production. In environmental matters, refractory companies throughout the world could take an active role in the removal, handling, disposal, and recycling of used refractory linings. In the global marketplace, several U.S. companies had opened plants in other countries. Opportunities could arise for companies to improve profitability by taking advantage of niche markets and expanded international business (Ceramic Industry, 1996, p. 58-59).

In Europe, steel production was growing at a rate of about 3% per year. Andalusite-based castable refractories were finding use in a number of steel plant applications. Zircon, metal powders, silicon carbide, and other materials can be added to andalusite-based castables to enhance their properties in corrosive environments. There was some evidence of growth in the aluminum- and glass-manufacturing sectors. Eastern Europe was believed to offer market potential as improvements in steel production promote the use of more efficient refractory materials (Skillen, 1996, p. 65-67).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS

(Dollars per metric ton)

1996	Price
Andalusite, Transvaal, 57.5% Al2O3, 2,000 metric ton bulk, f.o.b.1/	180 - 200
Andalusite, Transvaal, 59.5% Al2O3, 2,000 metric ton bulk, f.o.b.	220 - 240
U.S. kyanite, 54% to 60% Al2O3, 35-325 mesh, 18-ton lots, f.o.b. plant:	
Raw	140 - 168
Calcined	248 - 276
Sillimanite, South African, 70% Al2O3, bags, c.i.f. 2/ main European port	296

1/ "Free-on-board".
2/ "Cost, insurance, and freight."

Source: Industrial Minerals (London), December, 1996, No. 351, p. 73.

TABLE 2
U.S IMPORTS 1/ FOR CONSUMPTION OF ANDALUSITE 2/

Year	Quantity (metric tons)	Value 3/ (thousands)
1995	3,210	$623
1996	11,300	2,310

1/ Most material is from South Africa.
2/ Harmonized tariff schedule (HTS) number: 2508.50.0000.
3/ Customs value.

Source: Bureau of the Census.

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TABLE 3
WORLD KYANITE AND RELATED MINERALS CAPACITY
DECEMBER 31, 1996

(Thousand metric tons)

World region/mineral	Capacity 1/
North America:	
United States:	
Kyanite	W
Synthetic mullite	W
Total	W
South America:	
Brazil: Kyanite	1 e/
Europe:	
France: Andalusite	50 e/
Germany: Synthetic mullite	15 e/
Spain: Andalusite	5 e/
United Kingdom: Synthetic mullite	10 e/
Other countries	120 e/
Total	200 e/
Africa:	
Kenya: Kyanite	(2/) e/
South Africa:	
Andalusite	300 e/
Sillimanite	1 e/
Zimbabwe: Kyanite	2 e/
Total	303 e/
Asia:	
China: Unspecified	3 e/
India:	
Kyanite	11 e/
Sillimanite	19 e/
Total	30 e/
Japan: Synthetic mullite	40 e/
Total	73 e/
Oceania:	
Australia:	
Kyanite	1 e/
Sillimanite	(2/) e/
Total	1 e/
World total 3/	578 e/

e/ Estimated. W Withheld to avoid disclosing company proprietary data.

1/ For many countries, capacity is commensurate with their highest production during the past 5 years. (See table 4.)

2/ Less than 1/2 unit.

3/ Excludes U.S. kyanite and synthetic mullite.

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TABLE 4
KYANITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/ and commodity	1992	1993	1994	1995	1996 e/
Australia: e/					
Kyanite	800	800	800	800	800
Sillimanite 4/	100	100	100	100	100
Brazil: Kyanite e/	600	600	600	600	600
China: Unspecified e/	2,500	2,500	2,500	2,500	2,500
France: Andalusite e/	50,000	50,000	50,000	45,000 r/	45,000
India:					
Kyanite	10,101	11,359	6,265 r/	6,705 r/	7,000
Sillimanite	18,837	14,895	10,378 r/	9,705 r/	10,000
Kenya: Kyanite e/	(5/)	(5/)	(5/)	(5/)	(5/)
Korea, Republic of: Andalusite	38	18 r/	-- r/	-- r/	--
South Africa:					
Andalusite	230,333	187,708	206,291 r/	209,735 r/	210,000
Sillimanite	632	569	525 r/	317 r/	400
Spain: Andalusite e/	3,600	3,000	3,500	3,500	3,500
United States:					
Kyanite	W	W	W	W	W
Mullite, synthetic	W	W	W	W	W
Zimbabwe: Kyanite	1,990	878	567	600 e/	600

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Estimated data are rounded to three significant digits.

2/ Owing to incomplete reporting, this table has not been totaled. Table includes data available through Mar. 20, 1997.

3/ In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

4/ In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al2O3.

5/ Less than 1/2 unit.

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LEAD

By Gerald R. Smith

Domestic lead mine production increased for the third straight year, increasing by about 11% over that of 1995. Alaska and Missouri were the dominant producing States with a 93% share. Other appreciable lead mine production occurred in Colorado, Idaho, and Montana. Lead was produced at 17 mines employing about 1,200 people. The value of domestic mine production was about $460 million. Primary lead was processed at two smelter-refineries in Missouri, a smelter in Montana, and a refinery in Nebraska.

Secondary lead, derived principally from scrapped lead-acid batteries, accounted for 77% of refined lead production in the United States. Nearly all the secondary lead was produced by 18 companies operating 23 plants.

Two U.S. Government agencies issued several rules and notices pertaining to lead use and lead-based paint abatement. Another Government agency and industry announced a new voluntary initiative to significantly reduce worker exposure to lead. Congress passed an amendment to the Safe Drinking Water Act, thereby placing added restrictions on the use and sale of lead-containing materials in pipes and plumbing fixtures.

Lead was consumed in the manufacture of end-use products, including batteries, ammunition, covering for power and communication cable, building construction materials, and solders for motor vehicles, metal containers, and electrical and electronic components and accessories, in about 180 plants.

Lead-acid batteries continued to be the overwhelmingly dominant use of lead, accounting for about 87% of reported lead consumption. The Battery Council International (BCI) reported starting-lighting-ignition (SLI) battery production of 100 million units. This total included original equipment and replacement automotive-type batteries. An estimated 1.06 million metric tons (tons) of lead was consumed in SLI batteries.

Monthly sales of lead from the National Defense Stockpile (NDS) continued during 1996. Sales totaled about 38,700 tons (42,700 short tons), leaving about 389,000 tons (428,000 short tons) in the NDS at yearend.

Lead prices continued rising during the first 5 months, then generally declined throughout the remainder of the year. Although prices declined for a significant portion of the year, the average annual London Metal Exchange (LME) and North American Producer prices were each up by $0.065 per pound compared with the average prices of $0.286 and $0.423, respectively, in 1995.

Lead was mined in 45 countries; the top 5 accounted for 67% of the world's total production of 2.92 million tons. Australia was the largest producer, with 18% of the world total, followed by China, 17%; the United States, 15%; Peru, 9%; and Canada, 8%.

Legislation and Government Programs

Monthly sales of lead from the NDS continued during 1996. Lead disposal from stockpile inventory as a result of these sales totaled about 38,700 tons (42,700 short tons). The Defense National Stockpile Center's Annual Materials Plan (AMP) approved by the U.S Congress for fiscal year 1996 (October 1, 1995, to September 30, 1996) included a maximum disposal authority for lead of 54,400 tons (60,000 short tons). Under this authority, disposal of lead from NDS inventory during the first 9 months of calendar year 1996 was 32,500 tons (35,900 short tons). The AMP approved by the U.S. Congress for fiscal year 1997 (October 1, 1996, to September 30, 1997) also included a maximum disposal authority for lead of 54,400 tons (60,000 short tons). Under the fiscal year 1997 authority, disposal of lead from NDS inventory during the last 3 months of 1996 amounted to 6,200 tons (6,800 short tons), leaving about 389,000 tons (428,000 short tons) of lead at yearend.

The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Housing and Urban Development (HUD) issued several rules and notices pertaining to lead use and lead-based paint abatement. In February, EPA published a direct final rule regarding the prohibition on the use of lead or lead additives in gasoline for highway consumption. In that rule, consistent with the statutory regulations of the Clean Air Act, effective January 1, 1996, EPA revised its regulations so as to prohibit the introduction into commerce of gasoline for use as motor vehicle fuel that contains any lead additive or more than 0.05 gram of lead per gallon. The revisions also removed or modified any accompanying regulatory provisions such as recordkeeping and reporting requirements for refiners and importers and the necessity for motor vehicle manufacturers to place "unleaded fuel only" labels on the motor vehicle (U.S. Environmental Protection Agency, 1996c).

In March, EPA and HUD jointly issued a final rule on the requirements for disclosure of known lead-based paint and/or paint hazards in housing. Both agencies were directed under the Residential Lead-based Paint Hazard Reduction Act of 1992 to issue such regulations for persons selling or leasing housing constructed before the phaseout of the use of residential lead-based paint in 1978. According to the final rule, sellers and lessors must disclose the presence of known lead-based paint and/or lead-based paint hazards in the housing. They must also provide purchasers and lessees with a federally approved information pamphlet, as well as any available records or reports pertaining to such paint or hazards. Furthermore, purchasers must be provided with a 10-day opportunity to conduct a risk assessment or inspection for such paint or

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hazards before being obligated under any purchase contract. Sales and leasing contracts must also contain certain disclosure and acknowledgment language. Finally, agents must ensure compliance with all the requirements included in this final rule. The requirements were applicable on September 6, 1996, for owners of more than four residential dwellings and on December 6, 1996, for owners of four or fewer dwellings (U.S. Department of Housing and Urban Development and U.S. Environmental Protection Agency, 1996).

In July, HUD issued a request for comments from the general public, as well as affected Federal agencies, on the practical utility of collecting certain lead-based paint information through research grants issued by HUD (U.S. Department of Housing and Urban Development, 1996b). Subsequently, grants or cooperative agreements totaling $2.5 million were made available in November by HUD for research on specified topics related to the evaluation and control of residential lead-based paint hazards. As many as 10 awards ranging from $100,000 to $750,000 were to be issued on a competitive basis for applications received by the deadline of February 5, 1997. The Secretary of HUD was directed under the Residential Lead-Based Paint Hazard Reduction Act, Title X of the Housing and Community Development Act of 1992, to conduct such research in cooperation with other Federal agencies. Guidelines reflecting the Title X framework and describing state-of-the-art procedures for all aspects of lead-based paint hazard evaluation and control had been published by HUD in June 1995. The targeted research and field experience were expected to result in modifications to the original guidelines that would improve the accuracy of lead hazard evaluation and increase the effectiveness, and possibly reduce the cost of lead hazard control measures (U.S. Department of Housing and Urban Development, 1996a).

In other EPA actions, a final rule was issued on the requirements for complying with lead-based paint activities in target housing and facilities likely to be occupied by children. The rule was established, as directed under Title IV of the Toxic Substance Control Act, to ensure that individuals conducting activities involving the abatement of lead-based paint hazards are properly trained and certified, that training programs providing instruction in such activities are accredited, and that these activities are conducted according to reliable, effective, and safe work-practice standards. Starting on October 28, 1996, individual States and Indian Tribes were allowed to seek authorization, to administer and enforce the regulations set forth in the rule. Upon authorization by EPA, the administration and enforcement of the regulations will become effective as specified in the particular State and Indian programs. For States and Indian Tribes that do not apply for and receive authorization, EPA will administer and enforce the regulations no later than August 31, 1998 (U.S. Environmental Protection Agency, 1996a). EPA also announced that its National Lead Laboratory Accreditation Program, mandated by the U.S. Congress in Title X of the Residential Lead-Based Paint Hazard Reduction Act of 1992, had been revised. The specific revisions included expansion of the accreditation program to cover analysis for lead in field-operation laboratories and revised training requirements for laboratory personnel (U.S. Environmental Protection Agency, 1996b).

The Occupational Safety and Health Administration (OSHA), the Lead Industries Association, Inc., and the BCI jointly announced a new, voluntary, industry, 5-year initiative that will significantly reduce worker exposure to lead. Of the companies that produce or use lead, 33 agreed to participate in the program. Under OSHA's current standards, when the average blood lead concentration is at or above 50 micrograms per 100 grams of whole blood in a worker who is exposed to lead levels above the airborne action level of 30 micrograms per cubic meter, employers are required to relocate that worker to an area of lower lead levels until the blood lead level decreases to 40 micrograms per 100 grams, at which time the worker may be returned to the initial work area. In the new, 5-year initiative, the signatory companies agreed to reduce by 2 micrograms per 100 grams each year the blood lead level at which the worker is required to be relocated, and by 1 microgram per 100 grams each year the level at which the worker is subsequently allowed to return to the initial work area (U.S. Occupational Safety and Health Administration, 1996).

A bill amending the Public Health Service Act [the Safe Drinking Water Act, Public Law 104-182 (110 stat. 1613)] was passed by the U.S. Congress and signed by the President in August 1996. Included in the bill were amendments to the lead plumbing and pipes subsection that placed added restrictions on the use and sale of materials containing lead. Regarding the use of lead in plumbing and pipes, the act now states that no person may use any pipe, pipe or plumbing fitting or fixture, solder, or flux in the installation or repair of any public water system or any plumbing in a residential or nonresidential facility providing water for human consumption, that is not lead free. In the original act, effective June 19, 1986, the restrictions pertained only to the use of pipe and associated solder and flux that are not lead free. The act defines lead free as containing not more than 0.2% lead when referring to solders and flux, and not more than 8% lead when referring to pipes and pipe fittings. Regarding the sale of lead-containing plumbing and pipes, the act now states that it will be unlawful, effective August 6, 1998, for any person to introduce into commerce any pipe or any pipe or plumbing fitting or fixture, that is not lead free, except for pipe that is used in manufacturing or industrial processing. It will also be unlawful for any person engaged in the business of selling plumbing supplies, except manufacturers, to sell solder or flux that is not lead free. Furthermore, it will be unlawful for any person to introduce into commerce any solder or flux that is not lead free unless the solder or flux bears a prominent label stating that it is illegal to use the solder or flux in the installation or repair of any plumbing providing water for human consumption.

Production

Primary.—In 1996, domestic mine production of lead increased for the third straight year and was up by more than

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42,000 tons, or 11%, over that of 1995. Increases in production were reported at several of the major mines in Alaska and Missouri. The share of the U.S. mine output of lead derived from production in Alaska and Missouri remained unchanged at 93%. Other appreciable lead mine production occurred in Colorado, Idaho, and Montana. Domestic mine production data were derived from a voluntary survey on Lode-Mine Production of Gold, Silver, Copper, Lead, and Zinc by the U.S. Geological Survey (USGS). All the major lead producing mines responded to this survey. *(See tables 1, 2 and 3.)*

ASARCO Incorporated, New York, operated two mines, Sweetwater and West Fork, in southern Missouri that provided about 90% of the concentrate feed for its nearby smelter and refinery at Glover; the balance came from purchased lead concentrates. Zinc is an important coproduct of Asarco's mining business. The company's operation of a custom primary lead business at its East Helena, MT, smelter and Omaha, NE, refinery, depended principally on the availability of precious-metal-bearing lead concentrates from the United States and Latin America. In addition, Asarco owned a 60% share in the Leadville Mine in Colorado, managing the production of zinc, lead, and silver. Total production of lead in concentrates from Asarco's U.S. mining operations was about 99,000 tons in 1996, down about 12% from that of 1995 owing to declining ore grades. At yearend, Asarco reported total lead reserves of 14.8 million tons, with 9.5 million tons at a grade of 4.30% lead at its Sweetwater Mine, 5.0 million tons at a grade of 5.21% lead at its West Fork Mine, and 0.3 million tons at a grade of 2.91% at its Leadville Mine. To meet current environmental requirements for air and water emissions, Asarco completed modernization projects at its Glover and East Helena smelters. As a consequence of the company's 1995 decision to forego such an investment in its Omaha refinery, production of refined lead at Omaha was terminated in June. Asarco planned to sell the lead bullion produced at the East Helena custom smelter to refineries located outside of the United States (ASARCO Incorporated, 1996). *(See table 4.)*

In December, Asarco announced that it had reconsidered a decision made in October to close the Leadville zinc-lead-silver mine indefinitely at the end of 1996. As a result, full production was expected to be resumed by mid-March 1997. According to Asarco, a key factor in the decision to reopen the mine was the likely impact of the shutdown on the local community. The Leadville operation, a principal industry there, employs about 130 people and produces about 14,000 tons of zinc and 4,500 tons of lead in concentrate per year (Platt's Metals Week, 1996b).

The Doe Run Company, St. Louis, MO, operated five lead mines and four mills centered in southeastern Missouri, supplying concentrates to its smelter and refinery at Herculaneum, MO. Doe Run is owned by The Renco Group, a New York-based, privately held company with investments in natural resources and industrial operations.

Cominco Alaska Inc., a wholly owned subsidiary of Cominco Ltd., Toronto, Canada, operated the Red Dog zinc-lead mine in northwestern Alaska under a leasing agreement with NANA Regional Corp., owner of 100% interest in the property. NANA is a corporation organized under the provisions of the Alaska Native Claims Settlement Act. Recent modifications to the concentrator portion of the ore-processing system effectively increased lead recovery from the ore to 57%, compared with 37% in 1995; this resulted in a greater production of concentrate than that of 1995 but from 157,000 tons less of milled ore. In 1996, about 112,000 tons of lead concentrate (average grade 55.6% lead) was produced compared with about 92,000 tons (average grade 55% lead) in 1995. Ore reserves at the main Red Dog deposit were 50.1 million tons at a grade of 19.5% zinc and 5.3% lead, and inferred ore reserves at the newly discovered Aqqualuk ore body nearby were 76 million tons at a grade of 13.7% zinc and 3.6 % lead. As a result of the discovery of Aqqualuk, a plan was approved in 1996 to increase overall production at Red Dog by 40%. The expansion project will be carried out over a period of 3 years with full production at the expanded level expected to begin in 1999. In March, Cominco Ltd. purchased a 100% interest in the Pend Oreille zinc-lead mine near Metaline Falls, WA, from Resource Finance Corp., Toronto, Canada. During the year, excavation work was completed at the mine to provide access for further underground drilling and exploration. Considerable surface drilling was also carried out in an effort to locate possible extensions to the existing ore zone. Current ore reserves at Pend Oreille are estimated to be about 6 million tons at a grade of 7% zinc and 1% lead. According to Cominco, the concentrates derived from the Pend Oreille Mine would be used as an additional feed source for its Trail, Canada, smelter operations (Cominco Ltd., 1996).

Hecla Mining Company, Coeur d'Alene, ID, operated the Lucky Friday Mine in Mullan, ID, throughout 1996. Ore was processed at the rate of about 700 tons per day to produce silver-lead concentrate and zinc concentrate. About 97% of the lead was economically recovered using conventional flotation methods. In mine development activities during the year, Hecla focused on expanding its mining operations into the adjacent Gold Hunter silver-lead ore zone, about 1 mile northwest of the Lucky Friday Mine. An access draft was completed from the Lucky Friday Mine to the Gold Hunter zone, and exploratory drilling was begun in the second quarter of 1996. A final study on the feasibility of mining the Gold Hunter zone is expected to be completed in 1997, at which time a decision will be made on further development of this expansion project (Hecla Mining Company, 1996).

Mining was resumed at the Greens Creek polymetallic mine on Admiralty Island, near Juneau, AK, in the last quarter of 1996, a few months ahead of schedule, and the mine was expected to be back in full operation by the first quarter of 1997. In early 1995, a joint venture comprised of Kennecott Greens Creek Mining Company, a wholly owned subsidiary of Kennecott Minerals Corp., Salt Lake City, UT (70.3%) and Hecla Mining Company (29.7%) had begun redevelopment of Greens Creek, which had been placed on care and maintenance status in 1993 when low metal prices forced the operation to be shut down. The production from Greens Creek was expected to

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be about 38,000 tons of zinc and 19,000 tons of lead in concentrate per year in addition to 45,000 ounces of gold and 9 million ounces of silver per year. At these production rates, the combined reserves in three ore zones at Greens Creek were projected to be sufficient for a mine life of 17 years (Mining Journal, 1996d; The Mining Record, 1996).

Pegasus Gold Inc., Spokane, WA, mined and processed 5.08 million tons of gold-silver-lead-zinc ore at its Montana Tunnels Mine in central Montana; this output was approximately equal to that of 1995. About 90% of the lead was recovered from the ore. At yearend, proven and probable reserves totaled 17.1 million tons at a grade of 0.54 gram of gold, 10.6 grams of silver, 0.21% lead, and 0.62% zinc per ton, sufficient for a remaining mine life of about 3.5 years (Pegasus Gold Inc., 1996).

Chief Consolidated Mining Co., New York, NY, Akiko Gold Resources, Vancouver, Canada, and a U.S. subsidiary of Korea Zinc Co. Ltd., Seoul, Republic of Korea, formed a joint venture company, Tintic Utah Metals LLC, to develop the New Burgin lead-zinc-silver deposit in the Tintic district of Utah. The joint venture agreement effectively transferred a 50% interest in this deposit from Chief Consolidated to Akiko Gold (25%) and Korea Zinc (25%). Results of additional exploratory drilling increased the reserves at New Burgin to 1.5 million tons at a grade of 21% lead, 6.7% zinc, and 16.5 ounces of silver per ton. Lead production at New Burgin was expected to exceed 45,000 tons per year over a projected life span of 5 years (The Northern Miner, 1996a). The last reported lead mining activity at New Burgin was in 1978, when the mining operation was known as the Burgin Mine.

Secondary.—Domestic secondary production increased by about 8% in 1996. Secondary lead accounted for 77% of domestic lead refinery production compared with 73% in 1995. Lead recovered from scrap lead-acid batteries continued at a high level and accounted for 90% of all lead produced from secondary sources. The domestic secondary statistics were developed by the USGS from a combined secondary producer and consumer survey that included data from monthly and annual respondents. Of the 141 consuming companies to which a survey request was sent, 125 responded, representing an estimated 90% of the total U.S. lead consumption. Of the 25 companies producing secondary lead, exclusive of that produced from copper-based scrap, to which a survey request was sent, 18 responded, representing an estimated 99% of the total refinery production of secondary lead. Production and consumption for the nonrespondents were estimated by using prior-year levels as a basis. *(See tables 1, 5, 6, 7, 8, and 9.)*

RSR Corp., Dallas, TX, completed the expansion of its secondary lead production plant in Indianapolis, IN, during the second quarter of 1996. During the last half of the year, a second electric arc furnace, and an additional bag house and scrubber unit were placed into full operation, effectively increasing the production capacity of the plant by about 11,000 tons per year. At RSR's Middletown, NY, secondary lead production plant, work continued on the construction of a desulfurization unit that will produce sodium sulfate crystals as part of the secondary-lead-processing scheme (American Metal Market, 1996c). RSR also created a new division devoted to research that will improve lead smelting, refining, and fabricating methods. The new division, RSR Technologies, was formed from RSR's existing research and development department. It will service RSR Corp. facilities and the European operations of its parent company, Quexco Ltd., as well as other parties, such as lead-acid battery manufacturers (American Metal Market, 1996b).

General Smelting and Refining, Inc., College Grove, TN, announced plans to build a new secondary lead smelter that would replace the current facility and double the company's lead production capacity to about 27,000 tons per year. Application for a permit to build the new plant was forwarded to State and local authorities, as well as to the EPA during the last half of the year. Pending receipt of the required permits, it was anticipated that the new plant could be in operation within 2 years (American Metal Market, 1996a).

Asset Recovery, Inc., a financial investment and property management company in Wichita, KS, received approval from Oklahoma's Department of Environmental Quality to build a secondary lead smelter near Muskogee. Construction of the plant was scheduled to begin by yearend, with production expected to start by late 1997 or early 1998. The smelter facility will have the capacity to process about 15,000 spent lead-acid batteries per day, producing about 50,000 tons of secondary lead per year (American Metal Market, 1996d).

The Doe Run Company temporarily shut down its Buick secondary lead smelter in Boss, MO, in early December after encountering difficulties with its reverberatory furnace. The smelter was expected to be out of operation for about 6 weeks while the company relined the furnace. About 5,400 tons of lead production was likely to be lost during the shutdown period, according to company estimates. Total production of lead at the Buick facility for the company's fiscal year ended October 31, 1996 was 81,600 tons (Metal Bulletin, 1996e).

Consumption

Reported consumption of lead decreased by about 3% owing to the declining demand for lead in most end uses other than lead-acid storage batteries. Demand declined for uses including shot and bullets in ammunition, bearing metals in motor vehicles, sheet lead in building construction and medical radiation shielding, solder in building construction, motor vehicles and electronics, and pipes, traps and extruded products in building construction. The demand for lead in storage batteries showed a small increase of less than 1%. Consumption of lead in all forms of lead-acid storage batteries, SLI-type and industrial-type, represented 87% of the total reported consumption of lead. Industrial-type batteries include stationary batteries, such as those used in uninterruptible power-supply equipment for hospitals, computer and telecommunications networks, and in load-leveling equipment for commercial electrical power systems; as well as traction batteries, such as those used in industrial forklifts, airline ground equipment, and

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mining vehicles.

The BCI reported an SLI battery production of 100 million units in 1996 compared with 96.3 million units in 1995 and 99.2 million units in 1994. The totals include original equipment and replacement automotive-type batteries. By using an estimate of 10.6 kilograms (23.3 pounds) per unit, the SLI offtake for 1996 was about 1.06 million tons of lead. SLI batteries include those used for automobiles, buses, trucks, tractors, motorcycles, and marine craft. *(See tables 6, 7, 8, 9, 12, 13, 14, and 15.*

World Review

World production of refined lead remained at about 5.6 million tons in 1996, and world consumption increased from about 5.7 million tons in 1995 to 5.8 million tons. Commercial stocks of refined lead in industrialized countries declined to 0.55 million tons, or 4 weeks of consumption, at yearend 1996 compared with 0.59 million tons, or 5 weeks of consumption, at yearend 1995 and 0.75 million tons, or 7 weeks of consumption, at yearend 1994. Significant exports of refined lead to Western consumers from Eastern countries, notably China, continued during 1996, increasing by about 34% from the 1995 level of 247 thousand tons (International Lead and Zinc Study Group, 1996).

Lead prices continued to rise during the first 5 months of 1996 and then followed a generally declining trend throughout the remainder of the year. Although prices declined for a significant portion of the year, the average annual LME and North American producer prices were each up by $0.065 per pound compared with the average prices of $0.286 and $0.423, respectively, in 1995.

A number of changes occurred worldwide to affect the structure of the lead mining and refining industries, including the opening and development of new facilities, as well as the closing, reopening, expanding, selling, and modernizing of existing facilities. *(See tables 10 and 11).*

New Mines, Plants, Properties, Resources.—The Australian zinc-lead miner Western Metals began its first full year of production at the newly developed Goongewa Mine in Western Australia. In the initial 3 months of operation, 182,000 tons of ore were processed, producing 16,000 tons of zinc and 5,200 tons of lead in concentrate. All the concentrate production from the mine was exported to Asian consumers (Platt's Metals Week, 1996j; Metal Bulletin, 1996p). Additional Resources were discovered at the company's Cadjebut zinc-lead mine in Western Australia that were likely to extend the life of the mine another 4 years. Initial drilling results just south of the existing mine revealed a new ore zone containing 250,000 tons of resources at a grade of 11% zinc and 2% lead. Current production from the Cadjebut Mine is about 63,000 tons of zinc and 16,000 metric tons of lead in concentrate per year (Metal Bulletin, 1996q). The company further reported that it expected to complete final feasibility studies on its Blendevale zinc-lead mining project in the Kimberley region of Western Australia by early 1997. Western Metals, which holds a 60% interest in the project, a joint venture with Acacia Resources (40%), estimated that the mine would have a 10-year life, producing 182,000 tons of zinc and 42,000 tons of lead concentrates per year. Plant construction was scheduled to begin in mid-1997 with production of concentrates expected to start in mid-1998 (Metal Bulletin, 1996o).

Ireland's Ivernia West and Minorco Lisheen, joint developers of the Lisheen zinc-lead mine in County Tipperary, Ireland, submitted their application to authorities in January for authorization to develop the Lisheen deposit. The single detailed document sought approval from the Tipperary County Council for planning permission, the Department of Energy for a mining lease, and the Environmental Protection Agency for an environmental license. Pending a timely completion of the approval process, production could begin by mid-1998. Ore reserves at the Lisheen deposit total 2.3 million tons at a grade of 11.5% zinc and 1.9% lead. At the planned production capacity, these reserves will be sufficient for about 13 years of operation (Metal Bulletin, 1996j).

Ireland's Arcon International Resources was on schedule at yearend to begin shipment of concentrates from its Galmoy zinc-lead mine in County Kilkenny, Ireland, by early 1997. During the first year of operation, Arcon expected to process about 500,000 tons of ore, increasing to full capacity of 715,000 tons in the second year (Metal Bulletin, 1996f). The average ore grade, zinc plus lead, at Galmoy is about 12%, but continuing exploration activity during the year at a site adjacent to Galmoy revealed a significant new zone of zinc and lead resources. Drilling results obtained from two separate zones during the first 6 months of a 2-year drilling program increased total resources at Galmoy by an estimated 25%, to 8 million tons (Metal Bulletin, 1996l).

Boliden Mineral AB, Boliden, Sweden, started production during the year at its Los Frailes zinc-lead-copper mine in Sevilla, Spain, near Boliden's existing Aznalcollar Mine. The production at Los Frailes was expected to replace Boliden's source of zinc, lead, and copper now being mined at Aznalcollar, where reserves were nearly depleted by the end of the year. When full production is reached at Los Frailes in mid-1997, about 3.8 million tons of ore per year will be mined, yielding 110,000 tons of zinc, 45,000 tons of lead and 6,000 tons copper (Metal Bulletin, 1996g).

The Metal Mining Agency of Japan (MMAJ) reported the discovery of a significant, high-grade sulfide deposit in Japan's territorial waters west of the island of Okinawa. The hydrothermal deposit, in the form of sulfide mounds, was found to contain an average of 7.7% zinc and 4% lead and appreciable quantities of copper, gold, and silver. The deposit covered an area of 660,000 square meters in the 1,600-meter-deep Okinawa Trough. Scientists at MMAJ stated, however, that development of such a deposit may be more difficult than that of manganese sea nodules, for which experimental recovery and environmental impact studies have been completed (Mining Journal, 1996e).

Rhonda Mining Corp., Calgary, Canada, reported that drilling results from the Esker deposit on its Epworth property,

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Northwest Territories, revealed significant lead, zinc, and silver mineralization. Assays of initial drill samples showed ore grades of 1.36% to 10.8% lead, 0.04% to 2.13% zinc, and 0.06 to 0.61 ounces of silver per ton. Company geologists estimated that the Esker deposit could contain as much as 100 million tons of lead, zinc, and silver mineralization. Rhonda Mining owns the Epworth property with Noranda Mining and Exploration, Inc., Toronto, Canada, sharing equally in the development of the property (The Northern Miner, 1996b).

Farallon Resources Ltd., Vancouver, BC, Canada reported the discovery of an appreciable new sulfide deposit at its Campo Morado project in Mexico's Guerrero State. The new deposit, called South Naranjo, is just south of Farallon's Reforma sulfide deposit. Assay results from the company's drill-delineation program showed ore contents of as much as 7.6% zinc and 3.3% lead and significant quantities of copper, gold, and silver, (Mining Journal, 1996b).

Closings, Curtailments.—In October, Société Minière de Bougrine SA suspended mining and milling operations indefinitely at its zinc-lead mine in Tunisia. The decision was made following a determination that the required investment to lower operating costs was not justifiable in light of existing prices. Bougrine had opened its facilities in mid-1994, producing 38,000 tons of zinc and 6,300 tons of lead in concentrates in 1995. Inmet Mining Corp., Toronto, Canada, holds a 48% interest in the Bougrine mining and milling operations (Platt's Metals Week, 1996c).

Anvil Range Mining Corp., Toronto, Canada, temporarily suspended mining operations at its Faro lead-zinc mine, Yukon, Canada, in late December. The company cited weak metal prices, the strengthening Canadian dollar, and production below budgeted levels as reasons for its decision. Anvil expected to continue processing stockpiled ore at its mill during the first quarter of 1997 while company officials further review and assess Faro's operating status (Platt's Metals Week, 1996a).

Reopenings and Expansions.—In February, Peru's largest private lead miner, Compañía Minera Milpo, revealed investment plans to expand capacity by 10% at its Milpo mine and mill in Yanacancha, Pasco Department. The capacity of the Milpo concentrator is about 2,500 tons of ore per day. About 60% of Milpo's investment was to be directed toward exploration, and the remainder was to be used for upgrading the mine and mill. In conjunction with the upgrading, additional power was to be provided to the Milpo facilities through expansion of the company's La Candelaria hydroelectric plant. The added power was expected to be available by mid-1997 (Platt's Metals Week, 1996h).

China completed the expansion of its Shaoguan lead-zinc smelter in Guangdong Province, effectively doubling Shaoguan's lead production capacity to 60,000 tons per year. Although full production at the increased capacity was not projected to be reached until late 1997, about 40,000 tons of lead was expected to be produced in 1996. The expansion project also included the installation of two generators at the company's existing electric powerplant to meet the increased power demands at the smelter (Platt's Metals Week, 1996d).

Early in the year, Dalpolimetall, a lead and zinc producer in the Primorye region of Russia, began efforts to expand mining and milling capacity at its operations. As a result of a feasibility study conducted on behalf of the company's majority shareholder, Glencore International AG, Zug, Switzerland, Dalpolimetall recommended significant mill upgrades and the renewal of mining equipment. Also included in the recommendations was the maintenance and repair of underground mines covering the important Nikolayevsky and Soviet 2 Mines. The recommendations, if implemented, would nearly double the current production of lead in concentrate to 34,000 tons per year during a period of 5 years (Mining Journal, 1996a).

Gold Fields Namibia Ltd. reached agreement in October with its striking mineworkers, allowing for an anticipated resumption of operations at the Tsumeb, Namibia, lead and copper smelters by the end of the year. Gold Fields expected to obtain concentrates for the smelter operations from three of its mines, as well as from outside sources (Metal Bulletin, 1996n). The smelters had been closed for upgrading in August, but damage to the facilities incurred during the strike prevented them from being restarted as originally planned. Lead production capacity at the Tsumeb smelter operations is about 25,000 tons per year (Platt's Metals Week, 1996g).

Zambia's Kabwe Power and Metal Company (KPM) announced in October that it planned to reopen the Kabwe zinc-lead mine, which had been closed since May 1994. The mine had been purchased by KPM from Zambia Consolidated Copper Mines (ZCCM) earlier in the year. KPM was formed as a new company by a group of ZCCM's former Kabwe Mine employees after the mine closure. Production at Kabwe was expected to reach 18,000 tons of zinc and 13,000 tons of lead per year by 1999 and to extend over a 25- to 30-year life span (Metal Bulletin, 1996i).

In late 1996, Sweden's Boliden AB initiated efforts in late 1996 to expand its secondary lead smelter at Landskrona, Sweden. The expansion plan, still in the proposal stage by yearend, would increase Boliden's 40,000-ton-per-year lead and lead alloy production to 50,000 tons per year by 2000, if implemented. Currently about 3.5 million spent lead-acid batteries per year are processed at Landskrona to recover the lead and lead alloys (Metal Bulletin, 1996a).

Transfers of Ownership, Sales Offerings, Mergers.—China's, lead and zinc producer Shaoguan Smelter, Guangdong Province, announced that it planned to merge with the nearby Fankou lead-zinc mine and mill, pending final approval by the provincial government. Shaoguan had increased its demand for concentrate as a result of the addition of its second smelter and hoped to reduce smelter production costs through the use of concentrate from the Fankou mill rather than from other sources. Even with the additional supply of concentrate from Fankou, Shaoguan still expected to purchase about 30,000 tons of lead and zinc in concentrates per year from other domestic and foreign sources to meet the total demands of the smelting operations (Platt's Metals Week, 1996e).

Kazakstan's Ust-Kamenogorsk lead-zinc smelter and refinery

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and Zyryanovsky lead-zinc mining combine were expected to be operated under a new management system, according to information released in midyear. Ridder-Invest, a joint American-Kazakstani investment company, reportedly completed a trustee arrangement with the Government of Kazakstan to take over the two operations in exchange for significant investment to improve the facilities (Platt's Metals Week, 1996i).

In other actions taken by the Government of Kazakstan, the Chymkent lead smelter and refinery in southern Kazakstan will be managed by a new Kazakstani-Austrian joint venture company, RR Kazakstan Trade and Finance. As the manager, the joint venture company will retain a 31% share of Chymkent for a period of 5 years and will have a first option to buy this share at the end of the period. Plant staff will continue to hold a 44% share in Chymkent. The remaining 25% is expected to be sold, consistent with Kazakstan's overall privatization efforts. Production capacity of the smelter-refinery is 160,000 tons of lead per year, but production in 1995 was only 31,000 tons. RR Kazakstan hoped to increase annual production significantly at Chymkent, which was closed indefinitely in January as a result of difficulties in acquiring adequate feed materials and electrical power (Metal Bulletin, 1996h; Mining Journal, 1996c; Platt's Metals Week, 1996f).

Cominco Ltd. acquired a 25.5% interest in the Peruvian mining company Inversiones Colquijirca, whose 51% ownership in Sociedad Minera El Brocal will give Cominco an interest in the 2,100-ton-per-day Colquijirca zinc-lead mine near Tinyahuarco, Pasco Department. The estimated resource at the open pit Colquijirca Mine is 70 million tons at a grade of 7% zinc and 2% lead (Metal Bulletin, 1996d).

In August, Peru's State mining and smelting company, Centromin, announced that it planned to sell the Yauricocha polymetallic mine, Yauyos, Lima Department, as part of its ongoing privatization program. In two subsequent attempts to sell the mine, no firm offers were received by Centromin, although the sale reportedly attracted a number of interested buyers. By yearend, Centromin decided to restructure the sale to include an option for exploration of new deposits that have been discovered near the existing mine. About 350,000 tons of ore per year are processed at the mine, yielding 9,000 tons of zinc and 4,000 tons of lead. Reserves at Yauricocha total 2.8 million tons at a grade of 5.3% zinc and 2.8% lead and significant quantities of copper, gold, and silver (Metal Bulletin, 1996c; Mining Journal, 1996f,g).

Western Metals and Iscor, a South African steel and mining group, failed to reach a final agreement by yearend on Western's purchase of Iscor's Rosh Pinah zinc-lead mine in southwestern Namibia. A memorandum of understanding on the purchase of the mine had been signed in early July. Although negotiations continued throughout the remainder of the year, a Western official was quoted as saying, "...the circumstances of the parties have changed from those originally envisioned in the memorandum of understanding." Western reportedly had not ruled out further discussion, but said, "...any further discussions must take into account these changed circumstances" (Metal Bulletin, 1996m).

Renovation and Modernization.—In March, Metaleurop SA, Paris, France, resumed operations at its modernized lead smelter in Nordenham, Germany. By using the newly installed Ausmelt technology, production capacity of the smelter will be about 90,000 tons per year. Full production capacity was expected to be reached by the end of the year (Metal Bulletin, 1996b).

Pasminco Metals, Melbourne, Australia, approved the required expenditures to upgrade its primary lead smelter at Port Pirie in South Australia. The upgrades will increase refined lead production from the current 220,000 tons per year to 250,000 tons per year. Construction at Port Pirie was scheduled to begin in April 1997 with completion expected by the fall of 1997. Beginning in 1998, a portion of Port Pirie's concentrate feed will be derived from BHP Mineral's newly developed Cannington lead-zinc-silver mine, Queensland, Australia, beginning in 1998 (Metal Bulletin, 1996k).

Cominco Ltd. reached substantial completion of the construction of its new Kivcet lead smelter and slag fuming plant at the company's Trail facility. Commissioning of parts of the project were well under way in late 1996, and actual commencing of operations was scheduled for the first quarter of 1997 (Cominco Ltd., 1996).

In February, the Environment Ministers of the Organization for Economic Cooperation and Development (OECD) member countries and the European Environment Commissioner met in Paris, France, in February to discuss the subject of environmental management in an era of globalisation. As part of that meeting, the Ministers and the Commissioner adopted a declaration, "Risk Reduction for Lead," to advance national and cooperative efforts to reduce risks from exposure to lead. Highest priority was given to actions such as phasing down the use of lead in gasoline, eliminating exposure of children to lead in toys and other products with which they are in contact, eliminating the exposure to lead from food and beverage containers, and to other actions which address risks of exposure from food and beverages, water, air, and occupational environment (Organization for Economic Cooperation and Development Ministers, 1996). The OECD Council subsequently noted this ministerial-level declaration and instructed its Environmental Policy Committee to review the progress made on lead risk reduction by OECD member countries, to assess the need for further action in conformity with the declaration, and to develop a framework for the cooperation of industry in implementing voluntary industry programs for risk reduction on lead with a view to its wider applicability to other risk-reduction activities (Organization for Econonic Cooperation and Development Council, 1996).

Worldwide reserves of lead contained in demonstrated resources from producing and nonproducing deposits at yearend were estimated to be 69 million tons by the USGS. Reserves for the two largest producers in the world, Australia and China, were about 20 million and 7 million tons, respectively. The United States, the third largest producer in the world, had reserves of 8 million tons. The reserve base (reserves plus

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marginal economic deposits, measured and indicated) for Australia and China was 34 million and 11 million tons, respectively, and the reserve base for the United States was 20 million tons. The total world reserve base at the end of 1996 was estimated to be 120 million tons.

Outlook

According to Government analysts, the U.S. economy is expected to grow by as much as 2.5% in 1997. Consistent with this growth, motor vehicle production is expected to grow at a rate of about 2%, to 11.9 million new vehicles, and demand for lead in original equipment batteries will increase accordingly. Demand for replacement batteries in the automotive sector is likely to decline in early 1997 following an unusually mild winter, particularly in the more densely populated regions of the Eastern United States. Although the growing U.S. economy will provide the basis for continued strong demand for lead in 1997, any increase will be dependent to an appreciable extent on weather conditions during the summer and early winter. Significant temperature extremes during this period would increase the demand for replacement batteries, which represented about 60% of the U.S. demand for lead in 1996.

Mine production in the United States should increase by about 8% in 1997 as a result of continued higher production at some of the larger facilities. Total metal production from primary and secondary refineries in 1997 is expected to remain at about the level of 1996. Primary refinery production is expected to decrease slightly in 1997 as the industry makes adjustments during the first full year following permanent closure of one of its primary refineries. According to industry analysts, global production of refined lead was expected to increase by 3.4%, to about 5.8 million tons in 1997, and the global consumption of lead was forecast to increase by 2% to about 5.9 million tons. Mine production could decrease by nearly 5% on the basis of estimates that the output from Chinese mines could decline by as much as 28%. European mine production was forecast to increase by as much as 19% as a result of production increases in such countries as Ireland, Spain, and Sweden. Much of the increase in European mine production could be offset, however, by an anticipated 36% decline in Canadian mine production owing to the closing of one of its mines for an indefinite period of time (Mining Journal, 1997).

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TABLE 1
SALIENT LEAD STATISTICS 1/

(Metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Production:						
Mine, recoverable lead content 2/		397,000	355,000	363,000	386,000	426,000
Value	thousands	$307,000	$249,000	$298,000	$359,000	$459,000
Primary lead (refined):						
Domestic ores and base bullion		284,000	310,000	328,000	374,000	326,000
Foreign ores and base bullion		20,800	24,900	23,400	W	W
Secondary lead (lead content)		916,000	893,000	931,000	1,020,000 r/	1,100,000
Exports (lead content):						
Lead ore and concentrates		72,300	41,800	38,700	65,500	59,700
Lead materials, excluding scrap		71,700	60,300	74,200	65,300	121,000
Imports for consumption:						
Lead in ore and concentrates		5,310	483	473	2,600	6,570
Lead in base bullion		218	18	577	31	5
Lead in pigs, bars, and reclaimed scrap		191,000	196,000	231,000	264,000	268,000
Stocks, Dec. 31:						
Primary lead 3/		20,500	14,300	9,270	14,200	8,160
At consumers and secondary smelters		82,300	80,500	68,800	79,400 r/	71,700
Consumption of metal, primary and secondary		1,240,000	1,290,000	1,450,000	1,560,000 r/	1,530,000
Price: North American Producer average, delivered, cents per pound 4/		35.10	31.74	37.17	42.28	48.83
World:						
Production:						
Mine	thousand metric tons	3,060 r/	2,750 r/	2,790 r/	2,780 r/	2,920 e/
Refinary 5/	do.	2,950	2,980	2,910 r/	2,980 r/	2,830 e/
Secondary refinery	do.	2,350 r/	2,270 r/	2,350 r/	2,610 r/	2,650 e/
Price: London Metal Exchange, pure lead, cash average, cents per pound 4/		24.50	18.42	24.83	28.60	35.10

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Domestic ores and base bullion."

1/ Data are rounded to three significant digits, except prices.

2/ Lead recoverable after smelting and refining. Number in Table 10 represents lead in concentrate.

3/ American Bureau of Metal Statistics Inc.

4/ Platt's Metals Week.

5/ Primary metal production only; includes secondary metal production, where inseparable.

TABLE 2
MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY STATE 1/

(Metric tons)

State	1995	1996
Missouri 2/	359,000	397,000
Montana	8,350	7,970
Other States 3/	18,200 r/	21,200
Total	386,000	426,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes Alaska.

3/ Includes Colorado, Idaho, Illinois, New York, and Tennessee.

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TABLE 3
LEADING LEAD-PRODUCING MINES IN
THE UNITED STATES IN 1996, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of lead
1	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Zinc ore.
2	Buick	Iron, MO	The Doe Run Co.	Lead-zinc ore.
3	Casteel 1/	do.	do.	Do.
4	Fletcher	Reynolds, MO	do.	Do.
5	Sweetwater	do.	ASARCO Incorporated	Do.
6	West Fork	do.	do.	Do.
7	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Do.
8	Viburnum No. 29	Washington, MO	The Doe Run Co.	Do.
9	Viburnum No. 28	Iron, MO	do.	Do.
10	Montana Tunnels	Jefferson, MT	Pegasus Gold Corp.	Zinc ore.
11	Greens Creek	Southeastern, AK	Kennecott Minerals Co.	Do.
12	Leadville Unit	Lake, CO	ASARCO Incorporated	Do.
13	Sunshine	Shoshone, ID	Sunshine Mining Company	Silver ore.
14	Balmat	St. Lawrence, NY	Zinc Corporation of America	Lead-zinc ore.
15	Pierrepont	do.	do.	Do.
16	Coy	Jefferson, TN	ASARCO Incorporated	Zinc ore.
17	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co.	Fluorspar.

1/ Includes Brushy Creek Mill.

TABLE 4
REFINED LEAD PRODUCED AT PRIMARY REFINERIES
IN THE UNITED STATES, BY SOURCE MATERIAL 1/ 2/

(Metric tons unless otherwise specified)

Source material	1995	1996
Refined lead:		
Domestic ores and base bullion	374,000	326,000
Foreign ores and base bullion	W	W
Total	374,000	326,000
Calculated value of primary refined lead 3/	$348,000	$351,000

W Withheld to avoid disclosing company proprietary data; included with "Domestic ores and base bullion."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Total refined lead: American Bureau of Metal Statistics Inc.; domestic and foreign ores: U.S. Geological Survey calculations.

3/ Value based on average quoted price.

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TABLE 5
LEAD RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

		1995	1996
Kind of scrap:			
New scrap:			
Lead-base		49,600 r/	36,600
Copper-base		8,350 r/	8,330
Tin-base		--	--
Total		57,900 r/	45,000
Old scrap:			
Battery-lead		905,000 r/	992,000
All other lead-base		49,400 r/	56,400
Copper-base		8,720 r/	8,070
Tin-base		--	--
Total		963,000 r/	1,060,000
Grand total		1,020,000 r/	1,100,000
Form of recovery:			
As soft lead		584,000 r/	652,000
In antimonial lead		400,000 r/	424,000
In other lead alloys		19,200	7,970
In copper-base alloys		17,100	16,400
In tin-base alloys		1	1
Total		1,020,000 r/	1,100,000
Value 2/	thousands	$951,000 r/	$1,190,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Value based on average quoted price of common lead.

TABLE 6
U.S. CONSUMPTION OF LEAD, BY PRODUCT 1/

(Metric tons)

SIC Code	Product	1995	1996
	Metal products:		
3482	Ammunition: Shot and bullets	70,900	52,100
	Bearing metals:		
35	Machinery except electrical	W	W
36	Electrical and electronic equipment	298	W
371	Motor vehicles and equipment 2/	5,270	3,620
37	Other transportation equipment	W	W
	Total bearing metals	6,490	4,350
3351	Brass and bronze: Billets and ingots	5,260	5,460
36	Cable covering: Power and communication	5,640	W
15	Calking lead: Building construction	935	767
	Casting metals:		
36	Electrical machinery and equipment	W	W
371	Motor vehicles and equipment	W	W
37	Other transportation equipment	3,480	4,590
3443	Nuclear radiation shielding	W	1,130
	Total casting metals	18,100	18,800
	Pipes, traps, other extruded products:		
15	Building construction	2,210	1,810
3443	Storage tanks, process vessels, etc.	(3/)	(3/)
	Total pipes, traps, other extruded products	2,210	1,810
	Sheet lead:		
15	Building construction	18,000	14,000
3443	Storage tanks, process vessels, etc.	(3/)	(3/)
3693	Medical radiation shielding	9,960	5,400
	Total sheet lead	27,900	19,400

See footnotes at end of table.

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TABLE 6--Continued
U.S. CONSUMPTION OF LEAD, BY PRODUCT 1/

(Metric tons)

SIC Code	Product	1995	1996
	Solder:		
15	Building construction	3,220	1,650
	Motor vehicles, equipment, metal cans and shipping containers	8,260	4,580
367	Electronic components and accessories	4,190	2,350
36	Other electrical machinery and equipment	482	445
	Total solder	16,200	9,020
	Storage batteries:		
3691	Storage battery grids, post, etc.	711,000 r/	655,000
3691	Storage battery oxides	618,000 r/	681,000
	Total storage batteries	1,330,000 r/	1,340,000
371	Terne metal: Motor vehicles and equipment	(4/)	(4/)
27	Type metal: Printing and allied industries	(5/)	(5/)
34	Other metal products 6/	5,140 r/	5,130
	Total metal products	1,490,000 r/	1,460,000
	Other oxides:		
285	Paint	W	W
32	Glass and ceramics products	W	W
28	Other pigments and chemicals	7,880	W
	Total other oxides	61,700	56,900
	Miscellaneous uses	18,600 r/	14,000
	Grand total	1,560,000 r/	1,530,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in appropriate totals.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes "Terne metal: Motor vehicles and equipment."
3/ Included with "Building construction" to avoid disclosing company proprietary data.
4/ Included with "Bearing metals: Motor vehicles and equipment."
5/ Included with "Other metal products" to avoid disclosing company proprietary data.
6/ Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, electrowinning, and fishing weights.

TABLE 7
U.S. CONSUMPTION OF LEAD IN 1996, BY STATE 1/ 2/

(Metric tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California, Oregon, Washington	105,000	39,300	63,000	--	208,000
Florida and Georgia	7,840	7,350	--	--	15,200
Illinois	16,700	19,100	10,300	544	46,700
Iowa, Michigan, Missouri	38,700	29,800	31,100	--	99,600
Ohio and Pennsylvania	115,000	42,700	47,800	1,260	207,000
Arkansas and Texas	51,900	15,900	7,430	--	75,200
Alabama, Louisiana, Mississippi, Oklahoma	9,000	327	--	--	9,330
Colorado, Indiana, Kansas, Kentucky, Minnesota, Nebraska, Tennessee, Wisconsin	453,000	222,000	97,000	1,130	773,000
Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Vermont	52,100	24,800	19,800	--	96,700
Total	849,000	401,000	276,000	2,930	1,530,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes lead that went directly from scrap to fabricated products.

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TABLE 8
U.S. CONSUMPTION OF LEAD IN 1996, BY CLASS OF PRODUCT 1/ 2/

(Metric tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	50,600	60,000	9,530	2,890	123,000
Storage batteries	733,000	340,000	263,000	--	1,340,000
Other oxides	W	--	--	--	W
Miscellaneous	65,700	1,040	4,080	--	70,900
Total	849,000	401,000	276,000	2,890	1,530,000

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes lead that went directly from scrap to fabricated products.

TABLE 9
STOCKS OF LEAD AT CONSUMERS AND SECONDARY SMELTERS
IN THE UNITED STATES, DECEMBER 31 1/

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1995	35,400 r/	25,600 r/	18,300 r/	174	79,400 r/
1996	33,000	31,700	6,860	123	71,700

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 10
LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria e/	900	900	700	800 r/	900
Argentina	17,956	11,826	9,981 r/	10,521 r/	10,000
Australia	577,000	519,000	537,000	455,000	522,000 4/
Austria	920	1,340	--	--	--
Bolivia	20,002	21,220	19,679	20,387	16,200
Bosnia and Herzegovina e/	800	200	200	200	200
Brazil	2,517	117	806	-- r/	--
Bulgaria e/	39,000 e/	39,000 e/	37,600 r/	35,000 r/	21,000
Burma e/	2,800	2,200	2,300	2,400	2,500
Canada	343,808	182,234	167,584	204,227 r/	240,835 4/
Chile	298	344	1,008	1,010 e/	1,000
China e/	330,000	338,000	462,000	520,000 r/	500,000
Colombia	620	447	290	275 e/	275
Czech Republic e/ 5/	XX	1,000	500	--	--
Czechoslovakia e/ 6/	2,800	XX	XX	XX	XX
Ecuador e/	200	200	200	200	200
Finland	576	--	--	--	--
Georgia e/	800	500	400	300	200
Germany	1,485	--	--	--	--
Greece	28,300	26,400	22,800	20,400 r/	20,000
Honduras	10,797	3,551	2,810	2,619 r/	3,367 4/
India	30,500	26,000	30,500	28,600 r/	31,000 4/
Iran 7/	12,400 r/	14,700 r/	18,300 r/	15,900 r/	15,700
Ireland	42,900	48,300	53,700	46,143	45,344 4/
Italy	21,596 r/	7,404	13,902 r/	14,000 r/ e/	14,000
Japan	18,839	16,470	9,946	9,659	7,753 4/
Kazakstan e/	170,000	160,000	57,000 4/	40,000 4/	40,000
Kenya	--	396	350 r/	4 r/	--
Korea, North e/	75,000	80,000	80,000	80,000	80,000
Korea, Republic of	13,628	7,409 r/	2,173 r/	4,064 r/	5,131 4/

See footnotes at end of table.

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TABLE 10--Continued
LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Macedonia e/	15,000	15,000	15,000	15,000	15,000
Mexico	169,610	154,000	170,322	164,348	173,831 4/
Morocco	76,605	81,684	73,164	67,706 r/	71,668 4/
Namibia	15,000 e/	11,600	13,917	16,084 r/	15,349 4/
Nigeria e/	100	100	3,500 r/ 4/	3,500 r/ e/	3,500
Norway	3,767	1,698	3,096	1,462 r/	1,400
Peru	214,007 r/	224,695 r/	233,510	237,597 r/	248,787 4/
Poland	51,300 r/	49,100 r/	54,700 r/	58,100 r/	58,000
Romania	16,697	16,929	23,838	23,194 r/	18,712 4/
Russia e/	22,000	19,500	17,000	16,000	16,000
Saudi Arabia	-- r/	-- r/	-- r/	-- r/	--
Serbia and Montenegro	22,661	9,229	7,500	10,000 r/	17,000
Slovakia e/ 5/	XX	1,800	1,800	1,800	1,000
Slovenia e/	2,000	--	--	--	--
South Africa	75,806	100,171	95,824	88,449 r/	88,613 4/
Spain	30,447 r/	25,503 r/	23,753	30,346 r/	30,000
Sweden	105,295	111,709	112,787	100,070	100,000
Tajikistan e/	2,000	1,600	1,200	1,000	800
Thailand	11,880	6,050	7,950	9,680	20,000
Tunisia	1,362	2,000 r/ e/	2,856 r/	6,736 r/	4,765 4/
Turkey	10,800 e/	11,448	11,158	10,376 r/	10,000
United Kingdom e/	1,000	1,000	2,000 4/	1,600	1,800
United States	407,000	362,000	370,000	394,000	436,000 4/
Uzbekistan e/	35,000	25,000	15,000	10,000	10,000
Zambia 8/	4,446	7,027	--	--	--
Total	3,060,000 r/	2,750,000 r/	2,790,000 r/	2,780,000 r/	2,920,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 1, 1997.

3/ In addition to the countries listed, Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

6/ Dissolved Dec. 31, 1992.

7/ Year beginning Mar. 21 of that stated.

8/ Pb content of ore milled in year beginning Apr. 1 of that stated. Mine closed in June 1994.

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TABLE 11
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria:					
Primary e/	1,000	1,500	1,000	800	900
Secondary e/	3,500	7,100 r/	8,000 r/	7,800 r/	7,700
Total	4,500	8,600 r/	9,000 r/	8,600 r/	8,600
Argentina:					
Primary	14,597	12,473 r/	7,785 r/	2,430 r/	2,000
Secondary e/	15,000	16,000 r/	17,600 r/	26,298 r/ 3/	26,000
Total	29,597	28,473 r/	25,385 r/	28,728 r/	28,000
Australia:					
Primary	215,000	221,000	212,000	215,000	204,000 3/
Secondary	17,000	22,000	20,500	20,400	20,000
Total	232,000	243,000	232,500	235,400	224,000
Austria:					
Primary	5,727	4,779	410 r/	-- e/	--
Secondary	18,203	17,857	17,165	21,919 r/	22,000
Total	23,930	22,636	17,575 r/	21,919 r/	22,000
Belgium:					
Primary	75,297	105,712 r/	97,200	95,300 r/	94,400
Secondary	41,000	25,400 r/	26,300	26,400 r/	26,400
Total	116,297	131,112 r/	123,500	121,700 r/	120,800
Brazil:					
Primary	24,533	27,663	14,602	13,958 r/	15,000
Secondary	38,267	47,027	3,453	2,800 r/	3,000
Total	62,800	74,690	18,055	16,758 r/	18,000
Bulgaria:					
Primary e/	43,000	47,000	52,000 r/	62,200 r/	60,300
Secondary e/	10,100	10,000	10,000	10,000	10,000
Total	53,099	56,994	61,950 r/	72,150 r/	70,300
Burma: Primary	2,122	1,561	1,797	1,753	1,800
Canada:					
Primary	151,252	147,907	153,035	178,019 r/	194,031 3/
Secondary	101,633	69,107	98,605	103,372 r/	115,348 3/
Total	252,885	217,014	251,640	281,391 r/	309,379 3/
China: e/					
Primary	325,000	372,000	408,000	432,000 r/	430,000
Secondary	40,000	40,000	59,900	176,000 r/	100,000
Total	365,000	412,000	468,000	608,000 r/	530,000
Colombia: Secondary e/	3,600	3,600	3,500	3,500	3,500
Czech Republic: 4/ Secondary e/	XX	15,000 r/	15,000 r/	15,000 r/	15,000
Czechoslovakia: 5/ Secondary	24,000	XX	XX	XX	XX
France:					
Primary	161,000 e/	112,300 r/	105,250 r/	133,580 r/	135,000
Secondary e/	124,000 r/	146,000 r/	155,000 r/	156,000 r/	160,000
Total	284,060 r/	258,700 r/	259,950 r/	290,050 r/	295,000
Germany:					
Primary	175,322	174,595	189,435	190,000 e/	190,000
Secondary	179,000	159,561	142,249	145,000 e/	150,000
Total	354,322	334,156	331,684	335,000 e/	340,000
Hungary: Secondary e/	100	100	100	--	--
India: e/					
Primary	40,800	32,500	38,600	34,000 r/	32,500
Secondary	22,900	18,200	21,700	28,000 r/	27,000
Total	63,700	50,700	60,300	62,000 r/	59,500
Iran:					
Primary e/	--	14,600 r/	10,100 r/	4,000 r/	5,700
Secondary e/	42,000 r/	37,400 r/	41,200 r/	41,200 r/	41,200
Total	42,000 r/	52,000 r/	51,300 r/	45,200 r/	46,900
Ireland: Secondary e/	12,000	12,000	10,000	10,400 r/	10,000

See footnotes at end of table.

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TABLE 11--Continued
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Italy:					
Primary	102,000	89,900	91,700	84,900 r/	47,200
Secondary	84,300	92,900	114,200	95,500 r/	96,000
Total	186,300	182,800	205,900	180,400 r/	143,000
Jamaica: Secondary e/	1,000	800	800	800	800
Japan:					
Primary	218,787	212,145	182,621	149,523	140,531 3/
Secondary	111,374	97,307	109,641	137,011	146,842 3/
Total	330,161	309,452	292,262	286,534	287,373 3/
Kazakstan: e/					
Primary	180,000	125,000	75,000	88,500 r/ 3/	68,900 3/
Secondary	30,000	25,000	20,000	10,000	10,000
Total	210,000	150,000	95,000	98,500 r/	78,900
Korea, North: e/					
Primary	70,000	75,000	75,000	75,000	75,000
Secondary	5,000	5,000	5,000	5,000	5,000
Total	75,000	80,000	80,000	80,000	80,000
Korea, Republic of: e/					
Primary	63,000	88,000	86,457 r/ 3/	129,744 r/ 3/	88,556 3/
Secondary	25,000	10,000	10,000 r/	10,000 r/	10,000
Total	88,000	98,000	96,500 r/	140,000 r/	98,600
Macedonia: e/					
Primary	6,000	6,000	6,000	6,000	8,000
Secondary	2,000	2,000	2,000	2,000	2,000
Total	8,000	8,000	8,000	8,000	10,000
Malaysia: Secondary e/	28,500	29,000	33,200	33,600 r/	33,600
Mexico:					
Primary	167,000	178,419	170,322	160,322 r/	144,095 3/
Secondary e/	10,000	10,000	10,000	10,000	10,000
Total e/	177,000	188,000	180,000	170,000 r/	154,000
Morocco:					
Primary e/	69,400 r/	69,400 r/	61,800 r/	60,400 r/	59,700
Secondary e/	2,000	2,000	2,000	2,000	2,000
Total	71,400 r/	71,400 r/	63,800 r/	62,363 r/	61,749 3/
Namibia: Primary 6/	31,655	31,236	23,813	26,752	18,845 3/
Netherlands: Secondary	24,300	24,200	25,000 e/	25,000 e/	25,000
New Zealand: Secondary e/	5,000	3,000	6,000	6,000	6,000
Pakistan: Secondary e/	3,000	3,000	3,000	2,500	2,000
Peru:					
Primary	83,951	87,197	88,071	89,696 r/	94,923 3/
Secondary e/	5,000	5,000	5,000	-- r/	--
Total e/	89,000	92,200	93,100	89,700 r/	94,900
Philippines: Secondary	19,100	24,300	17,200	17,200 e/	17,200
Poland:					
Primary e/	38,700	47,300	46,300	51,400 r/	51,000
Secondary e/	15,000	15,000	15,000	15,000	15,000
Total	53,700	62,300	61,300	66,400 r/	66,000
Portugal: Secondary e/	7,400	8,300 r/	12,000 r/	12,000 r/	12,000
Romania:					
Primary	14,416	11,800	22,000	22,000 e/	20,000
Secondary	1,750	5,610	4,000	4,000 e/	5,000
Total	16,166	17,410	26,000	26,000 e/	25,000
Russia:					
Primary	18,000	17,500	15,700	15,000 e/	15,000
Secondary e/	14,500	14,100	12,700	12,000	12,000
Total e/	32,500	31,600	28,400	27,000	27,000
Serbia and Montenegro:					
Primary	23,265	6,393	4,458	11,468 r/	12,000
Secondary	390	--	--	--	--
Total	23,655	6,393	4,458	11,468 r/	12,000

See footnotes at end of table.

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TABLE 11--Continued
LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Slovenia: e/					
Primary	1,000	1,000	1,000	--	--
Secondary	3,000	3,000	5,424 r/ 3/	7,425 r/ 3/	7,000
Total	4,000	4,000	6,424 r/ 3/	7,425 r/ 3/	7,000
South Africa: Secondary	29,000	31,800	31,900	32,100	36,000
Spain: e/					
Primary	62,000	62,400	70,400	70,000	75,000
Secondary	58,000	61,000 r/	69,600	80,000 r/	80,000
Total	120,000	123,000 r/	140,000	150,000 r/	155,000
Sweden:					
Primary	54,111	46,752	46,600 e/	46,000 e/	45,000
Secondary	37,078	37,764	36,000 e/	36,000 e/	35,000
Total	91,189	84,516	82,600 e/	82,000 e/	80,000
Switzerland: Secondary	6,400	6,000	6,350	6,400 e/	6,400
Thailand: Secondary	18,906	17,060	16,904	19,070	19,000
Trinidad and Tobago: Secondary e/	1,800	1,700	1,600	1,600	1,600
Tunisia:					
Primary e/	913	500 r/	2,000 r/	2,800 r/	2,800
Secondary	5,400 r/	5,400 r/	5,500 r/	5,400 r/	5,400
Total e/	6,310 r/	5,900 r/	7,500 r/	8,200 r/	8,200
Turkey: e/					
Primary	3,000	3,000	4,000	5,000 r/	5,000
Secondary	2,100	2,000	2,100	2,000	5,000
Total	5,100	5,000	6,100	7,000 r/	10,000
Ukraine: Secondary e/	20,000	17,000	12,000	14,000	12,000
United Kingdom:					
Primary	198,805	209,560	191,036	149,706 r/	168,108 3/
Secondary	147,990	154,453	161,430	170,998 r/	177,466 3/
Total	346,795	364,013	352,466	320,704 r/	345,574 3/
United States:					
Primary	305,000	335,000	351,000	374,000	326,000 3/
Secondary	916,000	893,000	931,000 r/	1,020,000 r/	1,100,000 3/
Total	1,220,000	1,230,000	1,280,000 r/	1,390,000 r/	1,430,000 3/
Venezuela: Secondary e/	15,000	14,000	15,000	15,000	16,000
Zambia: Primary 7/	3,033	2,002	--	--	--
Grand total	5,230,000 r/	5,250,000 r/	5,260,000 r/	5,590,000 r/	5,480,000
Of which:					
Primary	2,950,000	2,980,000	2,910,000 r/	2,980,000 r/	2,830,000
Secondary	2,350,000 r/	2,270,000 r/	2,350,000 r/	2,610,000 r/	2,650,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 1, 1997. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead but exclude, to the extent possible, simple remelting of scrap.

3/ Reported figure.

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Dissolved Dec. 31, 1992. All production for Czechoslovakia in 1992 came from the Czech Republic.

6/ Includes products of imported concentrate.

7/ Data are for fiscal year beginning Apr. 1 of that stated. Smelter operation closed Mar. 1993. Production in 1993 includes secondary output and may all simply be remelt.

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TABLE 12
PRODUCTION AND SHIPMENTS OF LEAD PIGMENTS AND OXIDES IN THE UNITED STATES 1/ 2/

(Metric tons unless otherwise specified)

	1995				1996			
	Production		Shipments		Production		Shipments	
Product	Gross weight	Lead content	Quantity	Value 3/	Gross weight	Lead content	Quantity	Value 3/
White lead, dry	W	W	W	W	W	W	W	W
Litharge and red lead	6,230 r/	5,790 r/	15,700	$13,000,000	6,300	5,860	15,500	$13,800,000
Leady oxide	612,000 r/	582,000 r/	NA	NA	626,000	595,000	NA	NA
Total	620,000 r/	589,000 r/	NA	NA	634,000	602,000	NA	NA

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes basic lead sulfate to avoid disclosing company proprietary data.
3/ At plant, exclusive of container.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF LEAD PIGMENTS AND COMPOUNDS, BY KIND 1/

Kind	Quantity (metric tons)	Value (thousands)
1995:		
White lead carbonate	27	$63
Red and orange lead	63	174
Chrome yellow and molybdenum orange pigments and lead-zinc chromates	5,770	13,600
Litharge	18,500	14,200
Leady litharge	514	442
Glass frits (undifferentiated)	12,200	13,600
Total	37,000	42,000
1996:		
White lead carbonate	12	49
Red and orange lead	18	102
Chrome yellow and molybdenum orange pigments and lead-zinc chromates	8,970	23,500
Litharge	17,900	15,000
Leady litharge	119	113
Glass frits (undifferentiated)	16,800	17,800
Total	43,800	56,600

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 14
U.S. EXPORTS OF LEAD, BY COUNTRY 1/

(Lead content unless otherwise specified)

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Ore and concentrates (lead content):				
Australia	103	$32	90	$30
Belgium	23,100	6,540	20,300	5,750
Canada	27,000	8,840	24,200	7,250
India	790	106	302	88
Japan	8,670	2,450	11,600	3,290
Korea, Republic of	5,830	1,650	--	--
Netherlands	--	--	2,920	826
Trinidad and Tobago	62	19	144	64
Other	5 r/	10 r/	170	53
Total	65,500	19,600	59,700	17,400
Ash and residues (lead content):				
Belgium	5,580	3,450	7,720	4,690
Canada	2,260	1,150	10,800	5,090
Hong Kong	4	12	29	33
India	124	124	79	58
Other	71 r/	18 r/	742	59
Total	8,040	4,760	19,400	9,930
Unwrought lead and lead alloys (lead content):				
Australia	66	126	38	43
Belgium	1,190	1,880	236	672
Canada	2,850	2,440	25,800	44,100
Chile	496	895	--	--
China	302	234	324	280
Germany	470	413	58	204
Hong Kong	110	256	9	35
Indonesia	231	142	2	4
Israel	1,320	1,020	1,350	1,220
Japan	2,970	2,040	2,040	1,610
Korea, Republic of	19,800	12,800	19,800	16,800
Malaysia	752	493	1	22
Mexico	1,040	1,280	24,900	28,200
Morocco	158	55	--	--
Pakistan	26	29	--	--
Panama	33	69	10	22
Philippines	90	150	45	42
Singapore	18	49	99	107
Taiwan	16,200	10,400	10,000	9,650
United Kingdom	102	149	45	94
Other	32 r/	94 r/	485	926
Total	48,200	35,000	85,200	104,000
Wrought lead and lead alloys (lead content):				
Australia	8	41	160	161
Canada	3,400	3,890	3,090	3,690
Chile	5	30	339	606
China	(2/)	57	78	149
Costa Rica	109	212	29	73
Dominican Republic	144	137	14	29
Ecuador	4	15	102	72
Egypt	371	1,680	2	13
France	225	469	129	514
Germany	45	272	16	102
Guyana	144	85	--	--
Hong Kong	634	2,330	581	1,830
India	21	1,030	353	475
Japan	132	521	98	292
Korea, Republic of	360	1,100	307	938
Kuwait	81	646	89	1,210
Malaysia	24	426	65	498
Mexico	1,860	6,420	4,250	15,000
Netherlands	55	256	130	268
New Zealand	120	259	55	127
Nicaragua	1	5	125	159
Saudi Arabia	331	1,620	289	4,950

See footnotes at end of table.

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TABLE 14--Continued
U.S. EXPORTS OF LEAD, BY COUNTRY 1/

(Lead content unless otherwise specified)

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Wrought lead and lead alloys (lead content):				
Singapore	386	$609	831	$977
Sweden	37	122	48	986
Taiwan	104	188	86	482
Thailand	2	180	30	160
United Kingdom	112	485	5,080	5,200
Venezuela	67	128	24	49
Vietnam	37	55	--	--
Other	208 r/	1,200 r/	351	1,580
Total	9,020	24,500	16,700	40,600
Scrap (gross weight):				
Belgium	33	106	--	--
Canada	95,600	17,800	76,800 3/	10,100
China	93	122	47 3/	86
Germany	47	610	14 3/	204
Hong Kong	83	80	82 3/	60
India	407	104	633 3/	174
Israel	187	41	--	--
Japan	59	147	58 3/	71
Korea, Republic of	6,110	6,860	5,620 3/	6,070
Mexico	501	446	201 3/	44
Russia	76	173	--	--
Taiwan	277	388	20 3/	53
United Kingdom	299	461	--	--
Venezuela	609	1,220	728 3/	871
Other	122 r/	2,490 r/	1,090 3/	601
Total	105,000	31,000	85,300 3/	18,400

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Includes non-battery scrap data only.

Source: Bureau of the Census.

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TABLE 15
U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY 1/

(Lead content unless otherwise specified)

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Ore and concentrates (lead content): 2/				
Belgium	--	--	--	--
Canada	--	--	4,370	$941
China	54	$30	122	85
Korea, Republic of	--	--	--	--
Mexico	2,380	1,890	2,080	1,480
Peru	88	25	--	--
Other	72 r/	17 r/	--	--
Total	2,600	1,960	6,570	2,500
Base bullion (lead content):				
Canada	--	--	--	--
Other	31	27	5	2
Total	31	27	5	2
Pigs and bars (lead content):				
Belgium	25	46	11	32
Bulgaria	1,910	1,110	--	--
Canada	182,000	123,000	192,000	156,000
China	--	--	27	19
Colombia	--	--	239	146
France	25	47	--	--
Germany	3,140	2,270	338	672
India	207	191	607	360
Mexico	54,300	33,800	56,900	42,200
Peru	22,100	14,600	17,100	13,700
Sweden	5	8	--	--
United Arab Emirates	210	838	160	831
United Kingdom	128	82	19	31
Venezuela	364	233	--	--
Other	52 r/	31 r/	--	--
Total	264,000	176,000	268,000	214,000
Reclaimed scrap, including ash and residues (lead content): 3/				
Canada	75	36	106	63
Mexico	--	--	65	13
Other	--	--	21	28
Total	75	36	192	104
Grand total	267,000	178,000	274,000	217,000
Wrought lead, all forms, including wire and powders (gross weight):				
Canada	2,500	4,480	2,260	4,080
China	79	507	67	482
Colombia	20	17	176	95
France	53	86	71	334
Germany	242	1,370	200	1,250
Hong Kong	269	727	137	430
India	--	--	1,620	986
Italy	42	226	25	159
Japan	162	1,040	49	1,310
Mexico	1,970	1,800	2,630	1,740
Netherlands	12	59	132	713
New Zealand	46	538	88	710
Peru	17	14	939	742
Philippines	696	458	641	540
Taiwan	253	685	340	1,100
United Kingdom	93	822	111	878
Other	143 r/	885 r/	553	977
Total	6,600	13,700	10,000	16,500

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton, or greater than 100 troy ounces of total precious metals per short ton.

3/ Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

Source: Bureau of the Census.

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LIME

By M. Michael Miller

Lime is an important chemical with hundreds of chemical, industrial, and environmental uses in the United States. Its history probably dates back at least 4,000 to 6,000 years. The ancient Egyptians utilized lime as an ingredient in mortar and plaster. The Greeks, Romans, and Chinese utilized lime for construction, agriculture, bleaching, and tanning. Its uses began expanding with the advent of the industrial revolution, but it remained primarily a construction commodity until the rapid growth of the chemical process industries at the beginning of the 20th century. At the turn of the century, over 80% of lime consumed in the United States went for construction uses, but now over 90% of lime is consumed for chemical and industrial uses.

Lime is a basic chemical that was produced in 33 States and Puerto Rico, and its major uses were in steelmaking, flue gas desulfurization (FGD), pulp and paper manufacturing, construction, water purification, and ore concentration in the mining industry.

Total lime sold or used by domestic producers, excluding that from Puerto Rico, increased by about 600,000 metric tons (660,000 short tons) to 19.1 million tons (21.0 million short tons) in 1996. Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at more than $1.14 billion. Commercial sales increased by 500,000 tons (550,000 short tons) to a record high of 16.9 million tons (18.6 million short tons), and captive consumption was essentially unchanged at 2.17 million tons (2.39 million short tons). *(See table 1.)*

Production

The term "lime," as used throughout this chapter, refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO); (2) hydrated lime, calcium hydroxide [$Ca(OH)_2$]; (3) dolomitic quicklime (CaO•MgO); two types of dolomitic hydrate, (4) type N [$Ca(OH)_2$•MgO] and (5) type S [$Ca(OH)_2$•$Mg(OH)_2$]; and (6) dead-burned dolomite. Nondolomitic quicklime and hydrated lime are also called high-calcium lime. Lime also can be produced from a variety of other calcareous materials such as aragonite, chalk, coral, marble, and shell. Lime is also regenerated; that is, produced as a byproduct, by paper mills, carbide plants, and water treatment plants; however, regenerated lime is beyond the scope of this report.

Domestic production data for lime are developed by the U.S. Geological Survey from two separate, voluntary surveys of U.S. operations. The survey used to prepare this report is the annual "Lime" survey. Of the 107 operations to which the annual survey request was sent, 102 responded, representing 89% of the total sold or used by producers shown in table 2. Production for two nonrespondents was provided based on the monthly survey. Production for eight other nonrespondents was estimated using reported prior-year production figures.

In 1996, 57 companies produced lime from limestone or dolomite. Leading producing companies, in descending order, were Chemical Lime Co., with two plants each in Alabama, Arizona, Nevada, and Texas and one each in Idaho, Missouri, and Utah and two hydrating plants in California; Dravo Lime Co., with two plants in Kentucky, one plant in Alabama, and a hydrating plant in Louisiana; Mississippi Lime Co. in Missouri; Marblehead Lime Co., with two plants in Illinois and one each in Indiana and Michigan (although one of the Illinois plants and the Michigan plant closed during the year); Continental Lime Inc., with one plant each in Montana, Nevada, Utah, and Washington; Global Stone Corp., with one plant each in Michigan, Oklahoma, Tennessee, and Virginia; Martin Marietta Magnesia Specialties in Ohio; APG Lime Co., with one plant each in Texas and Virginia; Bellefonte Lime Co., with two plants in Pennsylvania; and U.S. Lime & Minerals, Inc., with one plant each in Arkansas, Pennsylvania, and Texas. These 10 companies operated 35 lime plants and 3 separate hydrating plants and accounted for 74% of commercial sales and 68% of total lime production.

Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance times the average 24-hour capacity of quicklime production, including quicklime converted to hydrated lime, and reported in short tons per year. In 1996, there were 36 commercial lime companies operating 64 lime plants; excluding combined captive and commercial producers, hydrating plants, and Puerto Rico. Capacity data were available from 28 commercial companies operating 52 plants. Based on the available data, the U.S. lime industry operated at 80% of capacity in 1996. This is a decrease from the 88% operating rate for 1995. The decrease in capacity utilization is the result of capacity additions outstripping production increases and a slightly different mix of reporting companies. Capacity utilization would be slightly lower if the capacity of several idle or mothballed plants were factored into the calculations.

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On a regional basis, capacity utilization ranged from 65% to 88%. In the Middle Atlantic Region (plants in eastern and central Pennsylvania, West Virginia, and northern Virginia) capacity utilization was 80%, based on data from seven companies operating nine plants. In the Southeast Region (plants in Alabama, eastern Tennessee, and southern Virginia) capacity utilization was 84%, based on five companies operating six plants. The utilization rate was probably higher in the Southeast. Incomplete data were reported for a sixth company estimated to be operating at near capacity levels, so the data were left out of the calculations. In the Eastern Midwest Region (plants in Michigan, northern Kentucky, Ohio, and western Pennsylvania) capacity utilization was 88%, based on five companies operating six plants. In the Western Midwest Region (plants in Illinois, Indiana, Iowa, Missouri, and Wisconsin) capacity utilization was 65%, based on 8 companies operating 10 plants. In the South Central Region (plants in Arkansas, Louisiana, Oklahoma, and Texas) capacity utilization was 78%, based on seven companies operating nine plants. In the Western Region (plants in Arizona, Colorado, Idaho, Montana, Nevada, Oregon, South Dakota, Utah, and Washington) capacity utilization was 87%, based on 6 companies operating 12 plants. *(See tables 2 and 3.)*

The lime industry continued to add capacity in 1996. Capacity additions were reported at plants in Ohio, Nevada, and Virginia, totaling 904,000 tons (997,000 short tons). Partially offsetting this new capacity was the closure of Marblehead Lime's Thornton plant in Illinois and its Brennan plant in Michigan. These closures accounted for about 557,000 tons (614,000 short tons) of annual production capacity. From 1993 through 1996, the lime industry added over 2.8 million tons (3.1 million short tons) of new capacity, while losing 765,000 tons (843,000 short tons) of capacity. The lost capacity was the result of the closure of Warner Lime Co. in 1993, Marine Magnesium Co. in 1994, and the two Marblehead Lime plants in 1996. Substantial amounts of additional new capacity are planned for 1997 and 1998.

In regional industry news, in the Southeast, A.P. Green Industries Inc. and SCANA Corp. announced a joint venture to build a new 180,000-ton-per-year (200,000-short-ton-per-year) lime plant at Charleston, SC. SCANA is an energy-based holding company and A.P. Green mines, processes, manufactures, and distributes specialty minerals and mineral-based products in both the United States and international markets. The plant will operate as Palmetto Lime LLC in conjunction with A.P. Green's subsidiary APG Lime. The plant is expected to start up in late 1997 with plans to double capacity by the year 2000. The plant is intended to serve FGD, pulp and paper, steel, and water purification markets (A.P. Green Industries Inc., 1996b). A.P. Green Industries also announced that it had reached an agreement in principle to acquire the Virginia lime plant and limestone reserves of Eastern Ridge Lime LP, an affiliate of Mississippi Lime. The Eastern Ridge operation will become part of APG Lime's Virginia operation. Eastern Ridge's Ripplemead lime plant will be designated as Plant #2 and its limestone production will be integrated with APG Lime's production (A.P. Green Industries Inc., 1996a). The startup of Global Stone Tenn Luttrell Inc.'s new vertical shaft kiln at its plant in Tennessee was delayed from 1996 to 1997. Reasons given for the delay were weather related construction delays and design deficiencies (Global Stone Corp., 1996a, b).

Blue Circle Cement Co. began work on a $40 million project to modernize and expand its lime plant in Calera, AL. When completed in late 1997, annual plant capacity will increase by 60% from 227,000 tons per year (250,000 short tons per year) to 363,000 tons per year (400,000 short tons per year). The project includes installation of a new Kennedy Van Saun 1,000-ton-per-day (1,100-short-ton-per-day) preheater rotary kiln, modernization of the hydrator system, and improvements to the quarry, storage, and load-out facilities (Blue Circle Cement Co., 1996).

Chemical Lime announced plans to build processing plants and storage terminals at deep water ports in Charleston, SC, and Tampa, FL. Lime initially will be shipped by rail from the company's Eastern Division plants in Alabama and Missouri, and later by water from a new lime plant to be built in the Caribbean scheduled for startup in 1998. Products intended for distribution will include high-calcium and dolomitic quicklime, blended products, and slurried products (Chemical Lime Co., 1996). Chemical Lime also began construction of a new lime plant at its O'Neal limestone quarry near Calera, AL. The new plant will operate a 1,225-ton-per-day (1,350-short-ton-per-day) preheater rotary kiln and is scheduled for startup during 1997.

In the Middle Atlantic Region, the two Pennsylvania lime plants of Wimpey Minerals PA Inc. changed hands twice during 1996. First, Wimpey Minerals became part of Tarmac America Inc., as a result of an asset swap between parent company George Wimpey Plc and Tarmac America. Then, as part of a plan finalized in December 1996, Tarmac America sold the Annville and Hanover lime plants and the Annville limestone quarry acquired from Wimpey to Carmeuse Pennsylvania, a division of Carmeuse Chimie Minerale of Belgium (Rock Products, 1997). Global Stone's subsidiary Global Stone Chemstone Inc. successfully restarted two idle vertical shaft kilns at its Strasburg, VA, plant (Global Stone Corp., 1996a). Also in 1996, Global Stone purchased the principal assets of the high-calcium limestone operation of Redland Genstar Inc., located near the Global Stone Chemstone lime operation. The Redland Genstar facility produces approximately 318,000 tons (350,000 short tons) per year of high-purity limestone products. The new property was to be merged with the Global Stone Chemstone facility (Global Stone Corp.,

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1996b). W.S. Frey Co. installed a second rotary kiln at its plant near Clearbrook, VA. The new kiln has a capacity of about 363 tons per day (400 short tons per day).

In the Midwest Region, Marblehead Lime closed its Brennan plant in Michigan and mothballed its Thornton plant in Illinois. Martin Marietta Magnesia Specialties Inc. received ISO 9002 certification for its Manistee, MI, and Woodville, OH, facilities. This is a quality assurance certification for production of all products produced at these facilities (National Lime Association, 1996). In addition, the company completed phase I of its capacity expansion project at its Woodville, OH, plant. The Ohio plant produces dolomitic quicklime for use at the company's magnesia plant in Manistee, MI, and sells to steel and related markets. Phase I increased lime plant capacity to about 700,000 tons per year (775,000 short tons per year). Dravo Lime's Black River Division in Carntown, KY, also received ISO 9002 certification in 1996 (Sommer, 1996). Vulcan Materials Co. started construction of a new dolomitic lime plant at an existing dolomite quarry near Manteno, Kankakee County, IL. Startup of the first straight rotary kiln was scheduled for the spring of 1997. Vulcan's McCook lime plant in Cook County, IL, was converted from dolomitic lime production to high-calcium lime production. The company was unable to access reserves at its McCook quarry, because of zoning difficulties, and had to start bringing in limestone from offsite to continue lime production.

In the South-Central Region, Chemical Lime restarted production at its Marble Falls, TX, plant, which had been idle since 1993.

In the Western Region, Chemical Lime added a new 1,225-ton-per-day (1,350-short-ton-per-day) preheater rotary kiln at its Apex lime plant near Las Vegas, NV. Continental Lime added a third kiln at its Pilot Peak plant near Wendover, NV. The new kiln is a preheater rotary with an annual capacity of about 910 tons per day (1,000 short tons per day) (McCaffrey and Robinson, 1996).

Consumption

Lime was consumed in every State, with the largest consuming States being, in descending order, Ohio, Indiana, Pennsylvania, Texas, and Michigan. Some States produce significantly more lime than is consumed within its own boundaries, for example, Alabama, Virginia, and Wisconsin. *(See tables 2 and 4.)*

The breakdown of consumption by major end uses was as follows: 62% for chemical and industrial uses, 28% for environmental uses, 8% for construction uses, and 1% for refractory dolomite. Captive lime accounted for about 11% of consumption and was used mainly in the production of steel in basic oxygen furnaces, in sugar refining, and in magnesia production. Almost all data on captive lime consumption, excluding the sugar industry, are withheld to protect company proprietary information. As a result, table 5, "Lime sold or used by producers in the United States, by use," has been revised to simply show the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table.

In steel refining, quicklime was used as a flux to remove impurities such as phosphorus, silica, and sulfur. Dolomitic lime was often substituted for a fraction of the high-calcium lime to extend refractory life. Dead-burned dolomite, also called refractory lime, was used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Lime consumption by the iron and steel industry increased by nearly 3% to 5.7 million tons (6.3 million short tons), even though U.S. raw steel production was essentially unchanged at 95 million tons (105 million short tons). Most of the increase in lime consumption was in electric arc furnace consumption. The steel industry accounted for about 30% of all lime consumed in the United States.

In nonferrous metallurgy, lime was used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and maintain the proper pH in the flotation process. Lime consumption for copper ore concentration increased by nearly 7% in 1996. It was used to process alumina and magnesia, to extract uranium from gold slimes, and in the recovery of nickel by precipitation. It was used in gold and silver recovery operations to control the pH of the sodium cyanide solution used to leach the gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a pH level between 10 and 11 to maximize precious-metals recovery and to prevent the creation of hydrogen cyanide gas. Lime consumption for concentration of gold, lead, silver, zinc, and other noncopper ores increased by 31% to 794,000 tons (875,000 short tons).

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Three of the four major treatment processes (Cyanisorb, alkaline chlorination, and SO_2/air) used to recover these cyanides use lime in the process. In the environmental sector, lime was used in the softening and clarification of municipal potable water. Lime was used to neutralize acid mine and industrial discharges. In FGD systems serving utility and industrial plants and incinerators, lime was used to react with sulfur oxides in the flue gas and was used to stabilize the resulting sludge before disposal. In 1996, the FGD market continued to display solid growth with lime consumption up nearly 5% to 2.82 million tons (3.11 million short tons).

In sewage treatment, lime's traditional role was to control

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pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and killing of bacteria. More recently, the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, has as its goal the reduction of odors, pathogens, and putrescibility of the solids. In lime stabilization, the basic process involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time.

The paper industry used lime as a coagulant aid in the clarification of plant process water. It was used, generally in conjunction with soda ash, for softening plant process water. This is a precipitation process to remove bivalent soluble calcium and magnesium cations (and to a lesser extent manganese, ferrous iron, zinc, and strontium), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

In the basic Kraft pulping process, wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat and where sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse. Lime consumption decreased by 11% reflecting the pulp and paper industry's improving process efficiencies.

Lime was used to make precipitated calcium carbonate (PCC), a specialty filler used in premium-quality coated and uncoated papers. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide is bubbled through milk-of-lime, a suspension of hydrated lime in water, to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals.

The chemical industry used lime in the manufacture of alkalies. Quicklime was combined with coke to produce calcium carbide, which was used to make acetylene and calcium cyanimide. Lime was used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk of lime was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself was then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide was obtained as a byproduct of lime production.

Dolomitic quicklime was used as a flux in the manufacture of glass. Quicklime was used to make calcium silicate building products such as sand-lime brick; hydrated lime was used to produce silica refractory brick.

In construction, lime was used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Quicklime was used in autoclaved aerated concrete to produce building materials that could be cut, drilled, and nailed like wood, but with the advantages of a concrete product. Hydrated lime was used with fly ash to make a base material, in asphalt mixes to act as an antistripping agent, and in plaster, stucco, and mortar to improve durability. *(See tables 5 and 6.)*

Prices

The average values per ton of lime rounded to three significant figures are discussed in dollars per metric ton with accompanying conversions into dollars per short ton. For accuracy, the conversions were made from the unrounded metric value and as a result may not be an exact conversion of the rounded values.

The average value of lime sold or used by producers, on an f.o.b. plant basis, increased only slightly in 1996 to $59.80 per ton ($54.30 per short ton). Average values per ton were $56.90 ($51.60 per short ton) for chemical and industrial lime, $60.20 ($54.60 per short ton) for environmental lime, $75.30 ($68.30 per short ton) for construction lime, $82.50 ($74.80 per short ton) for agricultural lime, and $88.80 ($80.60 per short ton) for refractory dolomite.

The average value of quicklime sold was essentially unchanged at $57.00 per ton ($51.70 per short ton). The average value per ton sold decreased slightly for chemical and industrial lime to $56.30 ($51.00 per short ton). The average value per ton sold for environmental lime increased by 8% to $57.70 ($52.40 per short ton). The average value per ton sold for construction lime decreased by 6% to $54.80 ($49.70 per short ton). The average value per ton of refractory dead-burned dolomite sold decreased by 6% to $89.40 ($81.10 per short ton). Almost no quicklime was sold as aglime.

The average value of hydrated lime increased by 10% to $79.60 per ton ($72.20 per short ton). Average values per ton sold increased by 6% for chemical and industrial lime to $69.10 ($62.60 per short ton), by 5% for environmental lime to $74.20 ($67.30 per short ton), by 16% for construction lime to $89.80 ($81.40 per short ton), and by nearly 4% for agricultural lime to $81.60 ($74.00 per short ton).

Foreign Trade

Exports of lime were about 50,000 tons (55,000 short

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tons), a decrease of nearly 31% compared with 1995. Exports went predominantly to Canada (73%), Jamaica (12%), and Mexico (7%). Imports of lime decreased by more than 9% to 262,000 tons (289,000 short tons). The United States imported quicklime, hydrated lime, and hydraulic lime, with nearly 83% coming from Canada and the remaining 17% coming from Mexico.

Current Research and Technology

Dravo Lime was awarded a grant by the Ohio Department of Development, Coal Development Office to test its magnesium-enhanced, lime scrubbing process in conjunction with Tecogen Corp.'s Tecolytic nitrogen oxide corona conversion process. The project calls for the capture of nitrogen oxide and sulfur dioxide from the gas stream in a wet scrubber system and monitoring the effects of the process variables on the removal efficiencies of sulfur dioxide and nitrogen dioxide. The process will produce a byproduct that can be used as fertilizer. The testing of these two technologies will be at Cinergy's Miami Fort Station (The Globe Online, 1996).

The U.S. Department of Energy awarded a contract to the University of Pittsburgh School of Engineering Center for Energy Research to evaluate the use of byproducts from advanced sulfur-removal systems in the treatment of metal-laden hazardous wastes. Lime is used in the scrubber systems at coal-fired powerplants to remove sulfur dioxide from flue gases. The residue from these scrubber systems contains unreacted lime and some useful chemicals formed when lime and sulfur dioxide react. The study will evaluate the use of 4 byproducts from sulfur removal systems to treat 10 characteristic metal-laden wastes. The goal is to stabilize the hazardous materials in the waste to allow the resulting nonhazardous waste to be disposed in landfills accepting nonhazardous wastes. Dravo Lime Co. is one of the two principal subcontractors on the project and will be responsible for sampling and analyzing the byproducts (University of Pittsburgh, 1996).

Adelaide Brighton Ltd., a major Australian cement and lime producer, and the University of Adelaide previously demonstrated the concept of precessing jet technology as applied in Gyro-Therm burners in rotary kilns producing cement clinker, alumina, and zinc oxide. The technology has now been applied to rotary kiln production of lime utilizing natural gas as the fuel. Natural gas burns cleaner than other kiln fuels, but provides poor heat transfer to the kiln charge. This means that more fuel has to be burned to transfer the same amount of heat to the kiln charge. The technology uniquely mixes the natural gas fuel and the surrounding air in the kiln so the gas burns in a fuel-rich area within the flame envelope despite the general oxygen-rich environment of the kiln. The results are improvements in production and fuel efficiencies and a significant reduction in nitrogen oxide emissions (Manias, Balendra, and Retallack, 1996).

Outlook

Lime has dozens of end uses in the chemical, industrial, and construction industries, but over 65% of consumption comes from six major markets: steel, flue gas desulfurization, water purification, pulp and paper, soil stabilization, and precipitated calcium carbonate.

Steelmaking is still the largest single end use for lime. U.S. steel production should continue at or near current levels as long as the economy stays out of a recession. In the long term, lime consumption will likely decrease because of industry changes in raw materials and flux usage, the latter includes greater use of flux pellets and hot metal desulfurization.

The FGD market continued to grow in 1996 with demand up by nearly 5%. The future continues to look promising for this market. Following recent trends and considering current market forces, the FGD market is expected to grow at a slightly faster rate than the overall lime market. During the period 1997-99, sales are expected to increase by about 5% annually. This would put 1999 FGD sales at between 3.25 to 3.30 million tons (3.58 to 3.64 million short tons). Phase II of the Clean Air Act Amendments, which takes effect January 1, 2000, and regulates small utility generating units, should provide an additional boost to lime sales after 1999. Lime scrubbers display favorable efficiencies and economics for these small units. Regulations covering small municipal incinerators and waste to energy incinerators also favor the use of lime scrubbers. Quantifying the increased demand generated by Phase II and other emissions regulations is difficult, but some industry projections have forecast FGD demand at 5 million tons (5.5 million short tons) by 2002. Major FGD lime producers are investing in research and development to lower the capital and operating costs associated with lime scrubbing and to produce salable byproducts. The goal of such research ultimately is to provide environmentally sound and economic technologies designed attract customers from powerplants currently utilizing limestone scrubbers or low-sulfur coal.

Soil stabilization sales increased by 20% in 1996, setting a new record by topping the million ton level. The soil stabilization market fluctuates depending on the level of highway and related types of construction, the weather, and competition from competing products like cement. Surprisingly, the use of lime in asphalt paving decreased by 35% in 1996 and has declined 42% since 1994. This has been touted as a growth market by the lime industry and this decrease is puzzling.

Demand in lime's traditional pulp and paper market decreased by 11% in 1996, as pulp and paper producers are regenerating more lime from their carbonate sludge for environmental and cost reasons. The market will remain a

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large, mature market for lime, but growth is expected to be flat at best. The PCC market increased by 14% in 1996, and should continue to grow as PCC attempts to expand into the groundwood paper and paper coating markets. Anticipated growth in the PCC market is expected to be particularly strong in the Southeastern United States.

Overall, commercial lime sales are expected to grow at about 3% per year over the next several years. The only major market force on the horizon is Phase II of the Clean Air Act Amendments, which may boost FGD sales after the year 2000.

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TABLE 1
SALIENT LIME STATISTICS 1/

(Thousand metric tons unless otherwise specified) 2/

		1992	1993	1994	1995	1996
United States: 3/						
Number of plants		112	112	109 r/	107 r/	108
Sold or used by producers						
Quicklime		13,700	14,200	14,800	15,800	16,500
Hydrated lime		2,230	2,250	2,290	2,390 r/	2,280
Dead-burned dolomite		302	315	300	308	271
Total		16,200	16,700	17,400	18,500	19,100
Value 4/	thousands	$950,000	$965,000	$1,020,000	$1,100,000	$1,140,000
Average value per ton		$58.60 r/	$57.60 r/	$58.80 r/	$59.20 r/	$59.80
Lime sold		14,300	14,900	15,500	16,400 r/	16,900
Lime used		1,890	1,870	1,910	2,180	2,170
Exports 5/		59	69	74	72	50
Value	thousands	$7,540	$7,830	$7,800	$8,490	$5,600
Imports for consumption 5/		193	201	204	289	262
Value	thousands	$15,000	$13,300	$13,100	$20,200	$19,400
Consumption, apparent 6/		16,300	16,900	17,500	18,700	19,300
World: Production		125,000 r/	123,000 r/	120,000 r/	121,000 r/	121,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ To convert metric tons to short tons multiply metric tons by 1.10231.

3/ Excludes regenerated lime. Excludes Puerto Rico.

4/ Selling value, f.o.b. plant, excluding cost of containers.

5/ Bureau of the Census.

6/ Defined as sold or used plus imports minus exports.

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TABLE 2
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1995 Plants	1995 Hydrated (thousand metric tons)	1995 Quicklime (thousand metric tons)	1995 Total (thousand metric tons)	1995 Value (thousands)	1996 Plants	1996 Hydrated (thousand metric tons)	1996 Quicklime (thousand metric tons)	1996 Total (thousand metric tons)	1996 Value (thousands)
Alabama	4	183	1,550	1,730	$105,000	4	196	1,660	1,860	$116,000
Arizona, Nevada, Utah	8	240	1,570	1,810	109,000	8	183	1,870	2,060	122,000
California	6	W	W	228	15,600	7	W	W	209	17,800
Colorado, Montana, Wyoming	10	5	340	346	21,600	10	18	321	340	33,000
Idaho, Oregon, Washington	7	23	643	667 r/	48,400	7	11	596	606	28,500
Illinois, Indiana, Missouri	8	451	3,000	3,450	188,000	9	451	3,250	3,700	205,000
Iowa, Nebraska, South Dakota	5	W	W	233	14,200	4	W	W	245	25,600
Kentucky, Tennessee, West Virginia	5	127	2,260	2,390	130,000	5	135	2,360	2,490	137,000
Michigan	9	38	615	653	34,600	9	3	581	584	30,300
Ohio	9	W	W	1,920	114,000 r/	8	W	W	2,020	107,000
Pennsylvania	8	256	1,390	1,640	107,000	8	276	1,250	1,530	105,000
Texas	6	526	843	1,370	85,800	7	462	894	1,360	86,300
Virginia	5	132	598	730 r/	41,900	5	124	642	766	45,700
Wisconsin	4	124	444	568	33,900	4	121	430	551	32,000
Other 3/	13	285 r/	2,890 r/	796 r/	48,200 r/	13	298	2,960	788	50,500
Total	107	2,390	16,100	18,500	1,100,000	108	2,280	16,800	19,100	1,140,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes Arkansas, Louisiana, Massachusetts, Minnesota, North Dakota, Oklahoma, Puerto Rico, and data indicated by the symbol W.

TABLE 3
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1/ BY RANGE OF PRODUCTION 2/

Range of production	1995 Plants	1995 Quantity (thousand metric tons)	1995 Percent of total	1996 Plants	1996 Quantity (thousand metric tons)	1996 Percent of total
Less than 10,000 tons	6	35	(3/)	13	82	(3/)
10,000 to 25,000 tons	17	232	1	13	210	1
25,000 to 50,000 tons	11	326	2	8	235	1
50,000 to 100,000 tons	18	1,330	7	16	1,070	6
100,000 to 200,000 tons	22	2,890	16	23	2,920	15
200,000 to 400,000 tons	22	5,850	32	22	5,720	30
More than 400,000 tons	11	7,870	42	13	8,860	46
Total	107	18,500	100	108	19,100	100

1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

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TABLE 4
DESTINATION OF SHIPMENTS OF LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons) 3/

	1995			1996		
	Quicklime	Hydrated lime	Total	Quicklime	Hydrated lime	Total
Alabama	545	46	591	645	54	699
Alaska	5	(4/)	5 r/	1	(5/)	1
Arizona	322	59 r/	381	338	41	380
Akransas	203 r/	27	231	275	28	303
California	285	78	363	358	65	423
Colorado	142	35	176	148	36	184
Connecticut	19	3	23	18	4	22
Delaware	38	6	44	69	7	76
District of Columbia	17	15	32	31	5	36
Florida	400	25	426	398	33	432
Georgia	241	79	320	249	70	318
Hawaii	(4/)	(5/)	(5/)	--	--	--
Idaho	219 r/	3	221 r/	146	5	151
Illinois	506	164	670	507	157	665
Indiana	1,460	32	1,490	1,600	31	1,630
Iowa	64	27	91	59	29	89
Kansas	74	23	97	105	19	124
Kentucky	444 r/	36	480 r/	469	33	502
Louisiana	318	107	425	431	120	551
Maine	3 r/	(4/)	3 r/	3	(5/)	3
Maryland	160	17	177	250	18	269
Massachusetts	145	12	157	144	12	156
Michigan	914	30	944	937	22	959
Minnesota	334	20	354	337	19	357
Mississippi	219	31	250	166	22	188
Missouri	135	60	195	132	50	182
Montana	139	19	158	126	34	160
Nebraska	54	11	65	53	10	63
Nevada	494	48	542	658	43	702
New Hampshire	2	(4/)	2	(5/)	(5/)	(5/)
New Jersey	154	23	177	219	33	253
New Mexico	127	38	165	118	28	147
New York	87	28	116	74	28	102
North Carolina	199	56	256	202	64	266
North Dakota	282	3	285	278	3	281
Ohio	2,220	177	2,390	2,330	145	2,470
Oklahoma	131	10	141	119	15	134
Oregon	155	25	180	156	17	174
Pennsylvania	1,630	174	1,800 r/	1,360	183	1,540
Rhode Island	2	1	3	2	1	3
South Carolina	255	42	298	259	42	301
South Dakota	24	3	27	25	4	30
Tennessee	211	52	262	211	58	269
Texas	802	511	1,310	774	446	1,220
Utah	303	27	331	297	17	315
Virginia	228	46	274	262	45	308
Washington	279	15	294	320	5	325
West Virginia	750 r/	48	799 r/	736	61	797
Wisconsin	144	40	184	112	43	156
Wyoming	186	18	204	233	23	256
Total	16,100	2,350	18,400	16,700	2,230	19,000
Puerto Rico	(4/)	18 r/	18 r/	(5/)	14	14
Canada	55	14	69 r/	55	6	61
Other 6/	23 r/	6	29 r/	31	25	56
Total	78 r/	38 r/	115 r/	86	46	132
Grand total	16,100	2,390	18,500	16,800	2,280	19,100

r/ Revised.

1/ Excludes regenerated lime.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons multiply metric tons by 1.10231.

4/ Revised to zero.

5/ Less than 1/2 unit.

6/ Includes other countries and U.S. possessions.

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TABLE 5
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1995		1996	
	Quantity 4/	Value	Quantity 4/	Value
Agriculture:	21	1,650	26	2,170
Chemical and industrial:				
Alkalies	72	3,050	72	3,070
Aluminum and bauxite	148	8,940	237	14,800
Food products, animal or human	13	910	25	1,580
Glass	156	8,510	159	8,930
Oil well drilling	23	1,490	26	2,020
Oil and grease	13	618	15	759
Ore concentration, other	605	31,600	794	38,800
Paper and pulp	1,020	61,600	908	54,500
Petrochemicals	28	4,230	23	4,230
Precipitated calcium carbonate	677	37,000	773	40,000
Steel:				
Basic oxygen furnaces	4,150 r/	237,000	4,030	226,000
Electric arc furnaces	952 r/	55,000	1,140	66,300
Argon oxygen decarburization	105	5,720	117	7,270
Ladle desulfurization, iron or steel	105	4,900	213	15,600
Other	263 r/	15,600 r/	226	12,800
Total steel:	5,570	318,000 r/	5,730	328,000
Sugar refining	826 r/	52,200	655	34,600
Tanning	19	1,180	23	1,380
Other chemical and industrial 5/	2,290 r/	138,000 r/	2,350	138,000
Total	11,500	668,000	11,800	671,000
Construction:				
Asphalt paving	210 r/	13,700	137	13,700
Finishing lime	82	8,790	71	9,340
Mason's lime	194	15,700	226	18,300
Soil stabilization	889	55,900	1,070	67,800
Other	92	10,300	71	9,820
Total	1,470	104,000	1,580	119,000
Environmental:				
Acid water, mine or plant	329 r/	21,000 r/	421	26,800
Flue gas sulfur removal	2,690 r/	141,000	2,820	164,000
Industrial solid waste treatment	61	3,740	38	3,290
Industrial wastewater treatment	60 r/	3,710 r/	64	4,580
Scrubber sludge solidification	68	3,830	86	5,740
Sewage treatment	554 r/	33,700	463	30,500
Water purification	1,160	67,800	1,170	70,400
Other	350 r/	19,700	368	21,800
Total	5,270 r/	294,000	5,440	327,000
Refractory lime (dead-burned dolomite)	308	28,100	271	24,100
Grand total	18,500	1,100,000	19,100	1,140,000

r/ Revised.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons multiply metric tons by 1.10231.

4/ Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for alkalies, copper ore concentration, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, mason's lime, and refractory lime (dead-burned dolomite).

5/ Includes calcium carbide, citric acid, copper ore concentration, magnesia from seawater or brine, magnesium metal, metallurgy, and unspecified uses.

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TABLE 6
HYDRATED LIME SOLD OR USED IN THE UNITED STATES, BY END USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1995		1996	
	Quantity 4/	Value	Quantity 4/	Value
Agriculture	20	1,580	26	2,080
Chemical and industrial:				
Oil and grease	13	618	14	704
Paper and pulp	8	554	6	441
Other 5/	463	30,500	395	26,400
Total	484	31,700	415	27,500
Construction:				
Asphalt paving	207	13,500	134	13,500
Finishing lime	82	8,790	71	9,340
Mason's lime	190	15,400	225	18,200
Soil stabilization	455	30,500	456	34,000
Other	91	10,300	70	9,760
Total	1,030	78,500	956	84,800
Environmental:				
Acid water, mine or plant	131	8,880	195	13,100
Industrial solid waste treatment	20	1,530	16	1,530
Industrial wastewater treatment	28	1,790	32	2,440
Sewage treatment	237	16,900	199	15,000
Water purification	288	20,500	264	19,600
Other	81	5,270	104	8,510
Total	784	54,800	811	60,100
Metallurgy 6/	77	4,420	71	7,910
Grand total	2,390	171,000	2,280	182,000

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons multiply metric tons by 1.10231.

4/ Quantity includes hydrated lime sold or used, where "used" denotes lime produced for internal company use for mason's lime and metallurgical uses listed in footnote 6.

5/ Includes alkalies, citric acid, food products (animal or human,) glass, oil well drilling, petrochemicals, precipitated calcium carbonate, sugar refining, tanning and unspecified uses.

6/ Includes aluminum and bauxite, basic oxygen furnace, copper ore concentration, electric arc furnace, other iron or steel, other ore concentration, wire drawing and unspecified metallurgical uses.

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TABLE 7
QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria	1,716	1,811	1,850	1,800 e/	1,800
Belgium e/	1,871 4/	1,750	1,750	1,800	1,800
Brazil e/	5,240 r/ 4/	5,700	5,700	5,700	5,700
Canada	2,380	2,380	2,390 e/	2,398 r/	2,491 p/
Chile (hydraulic) e/	1,300	1,300	1,250	1,006 4/	1,050
China e/	19,000	19,500	19,500	20,000	20,000
Colombia e/	1,300 r/	1,300 r/	1,300 r/	1,300 r/	1,300
Czech Republic 5/	XX	1,147	1,206	1,186	1,200
Czechoslovakia 6/	3,000 e/	XX	XX	XX	XX
France	3,000 e/	3,000 e/	3,015	2,940 r/	3,000
Germany	7,542	7,483	8,511	8,000 e/	8,000
Italy e/ 7/	3,600	3,600	3,500	3,500	3,500
Japan (quicklime only)	8,049	7,958	7,712	7,871	7,670
Mexico e/	6,500	6,500	6,500	6,580 4/	6,600
Poland	2,526	2,584	2,516	2,526 r/	2,500
Romania	1,738	1,738	1,621	1,747	1,700
Slovakia 5/	XX	1,070	1,000 e/	1,000 e/	1,000
South Africa (sales)	1,738	1,599	1,597	1,743 r/	1,691 4/
Turkey 8/	1,582	1,767 r/	1,800 e/	1,800 e/	1,800
U.S.S.R. e/ 9/	23,000	20,000	16,000	16,000	15,000
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States, including Puerto Rico (sold or used by producers)	16,200	16,800	17,400	18,500	19,100 4/
Other e/	8,953	8,538	8,678	8,913	8,908
Total	125,000	123,000 r/	120,000 r/	121,000 r/	121,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 20, 1997.

3/ Lime is produced in many other countries besides those included in the total. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available. Venezuela does not report production of lime, which is thought to be produced in very small amounts on individual farms.

4/ Reported figure.

5/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

6/ Dissolved Dec. 31, 1992.

7/ Includes hydraulic lime.

8/ Data are lime produced for steel production and do not include the widespread artisanal production of lime for whitewash and sanitation purposes.

9/ Dissolved in Dec. 1991. Total production of the former U.S.S.R.; information is inadequate to formulate reliable estimates for individual countries.

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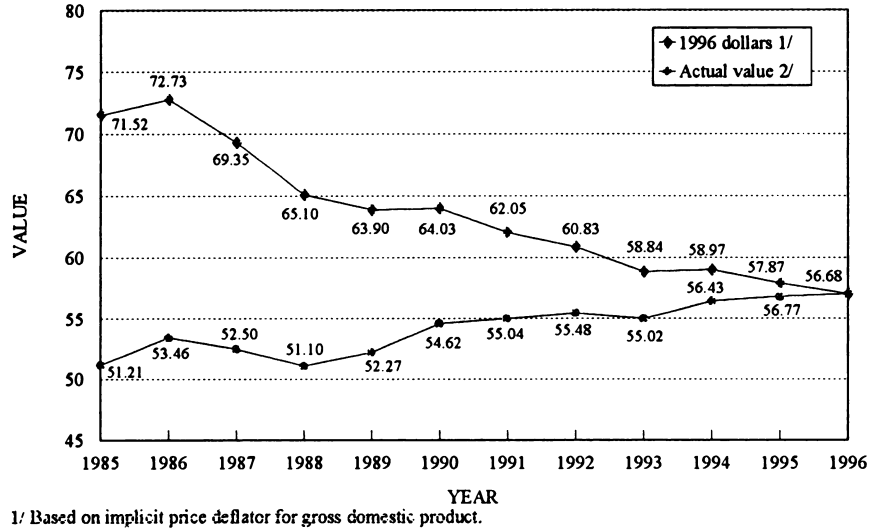
FIGURE 1

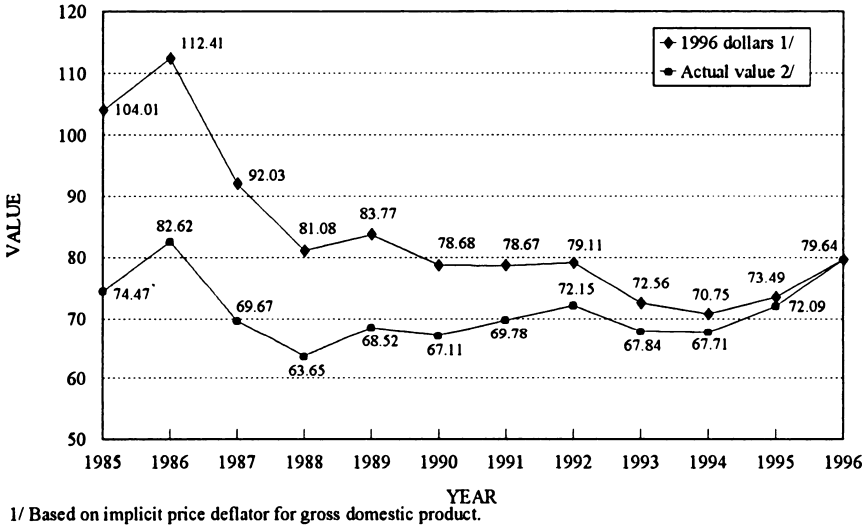
TIME-VALUE RELATIONSHIPS FOR QUICKLIME SOLD
(Dollars per metric ton)



1/ Based on implicit price deflator for gross domestic product.
2/ Value of lime sold as prepared for shipment, f.o.b. plant.

FIGURE 2

TIME-VALUE RELATIONSHIPS FOR HYDRATED LIME SOLD
(Dollars per metric ton)



1/ Based on implicit price deflator for gross domestic product.
2/ Value of lime sold as prepared for shipment, f.o.b. plant.

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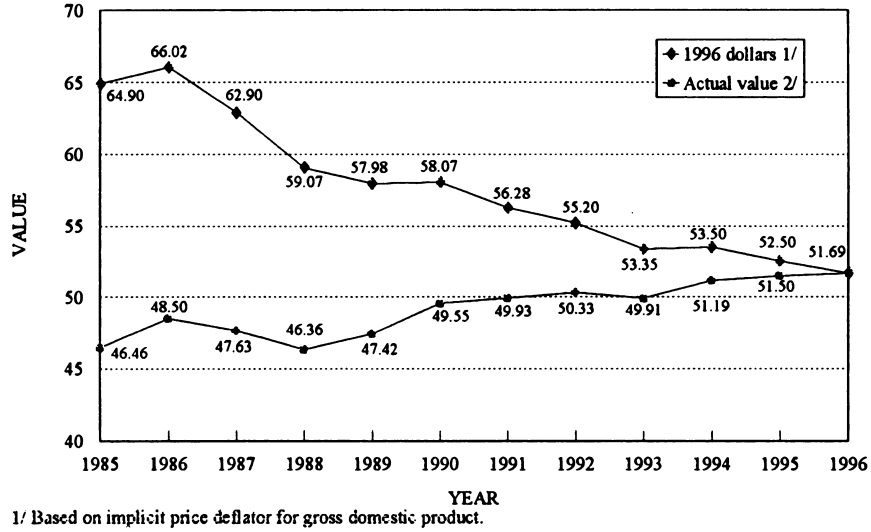
FIGURE 3

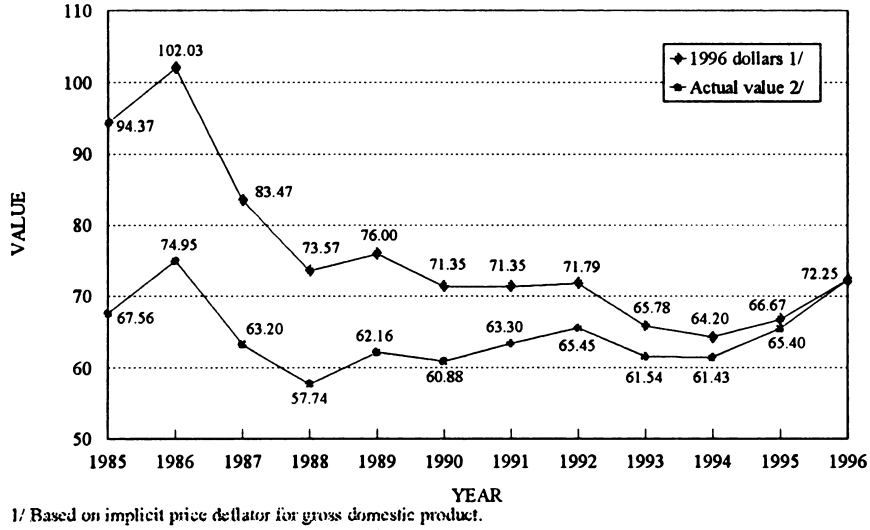
TIME-VALUE RELATIONSHIPS FOR QUICKLIME SOLD
(Dollars per short ton)



1/ Based on implicit price deflator for gross domestic product.
2/ Value of lime sold as prepared for shipment, f.o.b. plant.

FIGURE 4

TIME-VALUE RELATIONSHIPS FOR HYDRATED LIME SOLD
(Dollars per short ton)



1/ Based on implicit price deflator for gross domestic product.
2/ Value of lime sold as prepared for shipment, f.o.b. plant.

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LITHIUM

By Joyce A. Ober

The United States has been the largest producer and consumer of lithium and its compounds, and two U.S. companies have been the leading lithium carbonate producers in the world for many years. Chile, an increasingly important player in the lithium industry, may become the world lithium leader by the end of this century with the completion of a second lithium operation late in 1996.

Because lithium is electrochemically reactive and has other unique properties, there are many commercial lithium products. Producers sell lithium as mineral concentrate, brine, compound, or metal depending on the end use. Most lithium compounds are consumed in the production of ceramics, glass, and primary aluminum.

Legislation and Government Programs

During the 1950's and 1960's, the U.S. Government nuclear weapons programs required lithium hydroxide monohydrate for the recovery of the lithium-6 isotope used in the production of tritium, a compound necessary for nuclear fission reactions. When the U.S. Department of Defense discontinued these programs, a stockpile of lithium hydroxide monohydrate remained, about 75% of which had been depleted of the lithium-6 isotope. The processed material contained up to 8 or 9 parts per million of mercury. The U.S. Department of Energy (DOE) took over administration of the stockpile in 1988.

In 1993, DOE completed an environmental assessment of the material to determine if sales of the mercury-contaminated material presented a risk to environmental quality. After issuing a "Finding of No Significant Impact," the material was offered for sale. After negligible sales in 1993 and 1994, the remaining stocks of about 41,000 metric tons of lithium hydroxide were sold in 1995.

Toxco, Inc., a lithium product recycler based in Anaheim, CA, bought about 31,000 tons of processed material, and Cyprus Foote Mineral Co., a major lithium producer based in Kings Mountain, NC, purchased 10,000 tons of virgin lithium hydroxide monohydrate. The sale was complicated by the condition that Toxco and Cyprus Foote could purchase only 70% of the stockpile processed material and virgin lithium hydroxide monohydrate, respectively, until DOE offered the remainder to the general public at the same prices paid by the two companies. In early 1996, the processed material was offered at 13¢ per pound, and the virgin material, at 18.3¢ (U.S. Department of Energy, 1995); no additional sales were announced. Toxco took delivery of about 900 tons of DOE lithium hydroxide monohydrate in 1996. Toxco intended to market the DOE material, as well as the lithium salts from its recycling operation, for use in the U.S. construction industry as an additive to Portland cement concrete. The company has formed a marketing division, LithChem International to market its material. This information was confirmed by William McLaughlin (Toxco, Inc., oral commun., 1997).

Production

The U.S. Geological Survey collects domestic production data for lithium from a voluntary survey of U.S. operations. Two U.S. companies responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data. *(See table 1.)*

Cyprus Foote produced about 6,400 tons of lithium carbonate from its brine deposit in Silver Peak, NV (Cyprus Amax Minerals Co., 1997). In addition to its Nevada operation, Cyprus Foote, the world's largest lithium company and a subsidiary of Cyprus Amax Minerals Co., owns a spodumene mine in Kings Mountain that has been inactive since 1991. The lithium carbonate plant in Kings Mountain was dismantled in 1994. A new lithium hydroxide production facility was completed at Silver Peak in the second quarter of 1996; the lithium hydroxide plant in Sunbright, VA, was closed in August. The company operates a butyllithium plant in New Johnsonville, TN. Cyprus Foote also owns and operates a large lithium operation in Chile.

FMC Corp., Lithium Div., mines spodumene, a lithium ore, from pegmatite dikes near Bessemer City, NC. FMC also produces lithium carbonate and a full range of downstream compounds, including lithium metal and some organic lithium compounds, at a chemical plant near the mine and operates a butyllithium plant in Bayport, TX. FMC is developing a large lithium brine operation in Argentina. Upon the completion of this project, expected in early 1997, FMC intends to phase out mining in North Carolina but will maintain all the other facilities at its operations there.

Lithium carbonate is the most important lithium compound produced from brine and ore deposits. Spodumene was the major raw material required for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate were produced for sale. Spodumene is the most common lithium ore, but petalite and lepidolite are other types that are mined in different parts of the world. These three are beneficiated to produce lithium ore concentrates that can be consumed directly in certain applications. Spodumene concentrates and brines are converted to lithium carbonate and then to other compounds for consumption in other end uses.

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Extracting lithium from spodumene entails an energy-intensive chemical recovery process. After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. Concentrate is heated to 1,075 °C to 1,100 °C, changing the molecular structure of the mineral and making it more reactive to sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250 °C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Production of lithium carbonate from brine is much less energy intensive than that from spodumene. Nevada brines enriched in lithium chloride, averaging about 300 parts per million when operation began in 1966 (Engineering and Mining Journal, 1970), are pumped from the ground and progress through a series of evaporation ponds. Over the course of 12 to 18 months, concentration of the brine increases to 6,000 parts per million lithium through solar evaporation. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped. Approximately the same process is used to recover lithium from the Chilean brines, with slight adjustments to account for their different chemistries.

Consumption

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries consumed most of the lithium minerals and chemicals sold in 1996. Estimated domestic consumption increased slightly from 1995. Ceramics and glass production and aluminum smelters were the largest consumers of lithium carbonate and lithium concentrates in the United States, composing an estimated 20% and 18% of the lithium market, respectively. Other consuming industries were synthetic rubber and pharmaceuticals, 13%; chemical manufacturing, 13%; miscellaneous chemicals, 12%; lubricants, 11%; batteries, 7%; and air treatment, 4% (Cyprus Minerals Co., 1993).

The largest consumer of lithium compounds in the United States are lithium carbonate and mineral concentrate additions in ceramics and glass manufacturing processes. These additions lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The domestic manufacture of thermal shock-resistant cookware (pyroceramics) consumes the majority of lithium used in the ceramics and glass industry. The manufacture of black-and-white television picture tubes consume significant amounts of lithium concentrates overseas. Low-iron spodumene and petalite are sources of the lithium used to improve the physical properties of container and bottle glass and as a source of alumina, another important component of the glass. Glass manufacturers use lithium in container and bottle glass, enabling them to produce lighter weight, thinner walled products.

The second largest consumers, aluminum producers, add lithium carbonate to aluminum potlines to lower the melting point of the bath, allowing a lower operating temperature for the potline, and increasing the electrical conductivity of the bath. These factors contribute to increased production or reduced power consumption, as well as to the indirect benefit of lower fluoride emissions.

The third largest end use for lithium compounds is as catalysts in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium initiates the reactions between styrene and butadiene that form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds are catalysts for the production of plastics, such as polyethylene. Lithium metal and compounds also are used by pharmaceutical manufacturers in the production of vitamin A, some steroids, an anticholesterol agent, an analgesic, antihistamines, tranquilizers, sleep inducers, contraceptives, and other products. Pharmaceutical-grade lithium carbonate is approved directly for the treatment for manic-depressive psychosis. This is the only treatment approved by the U.S. Food and Drug Administration in which lithium is consumed by the patient.

The multipurpose grease industry was another of the important end uses for lithium in 1996. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-base greases are favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be used in military, industrial, automotive, aircraft, and marine applications.

Almost all major battery manufacturers marketed some type of lithium batteries, and research and development continued. These batteries represent a growth area for lithium consumption, and new battery configurations continue to be developed. Continued interest in electrically powered vehicles spurred additional interest in battery research. New, more efficient types of rechargeable (secondary) lithium batteries have been developed and improved to meet the requirements of this market and of electronic equipment, such as portable telephones and video cameras. Work continued on lithium ion batteries. These batteries are of particular interest because they take advantage of the large power capacity available from lithium batteries with fewer safety problems than encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture.

Nonrechargeable (primary) lithium batteries offer improved performance over alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in watches, microcomputers, cameras, small appliances, electronic games, and toys. The military purchased large and small lithium batteries for a variety of military applications. The Galileo spacecraft, launched in October 1989 by the National Aeronautics and Space Administration (NASA)

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for its 6-year trip to explore the atmosphere of Jupiter, contained lithium sulfur dioxide batteries to power its scientific instruments when it reached its destination (Battery Technology, 1990). Recent modifications to the lithium sulfur dioxide battery have extended the life of the batteries to at least 10 years with little or no reduction in performance. The final disposition of lithium batteries is of concern. Until recently, no method was available for the safe and economic disposal of large lithium batteries, especially the military types. In 1994, Toxco developed a process for recycling lithium battery components and opened a facility for the neutralization, disposal, and recycling of lithium batteries, primarily large military types, in Trail, British Columbia (Vimmerstedt and others, 1995, p. 25, 26).

Aircraft manufacturers in several countries are using or are considering the use of aluminum-lithium alloys for wing and fuselage skin or structural members in different types of aircraft. Use of these alloys can reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are attractive to the aircraft and aerospace industries because of their reduced density and superior corrosion resistance compared with those of conventional aluminum alloys. These alloys are not as widely used in aircraft manufacture as was hoped at the initial introduction of the alloys. In airplane construction, these alloys face direct competition from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers.

During 1996, NASA began testing a new design for the external fuel tank used on the space shuttle (the only part that is not reused). The super-light-weight tank, designed by Lockheed Martin Manned Space Systems, is constructed of an aluminum-lithium alloy containing 1% lithium, 4% copper, 0.4% silver, 0.4% magnesium, and the remainder aluminum. This alloy is 30% stronger and 5% less dense than the aluminum alloy previously used. The redesigned fuel tank will weigh about 3,400 kilograms less than the current design; the weight savings can be used to increase the payload capacity for future shuttle missions. Tests continued throughout the year at NASA's Marshall Spaceflight Center in Huntsville, AL, and results were expected early in 1997 (Lockheed Martin Corp., 1996). The new tank design is expected to be used first during the shuttle launches carrying the initial portions of the international space station (National Aeronautics and Space Administration, 1997).

Small quantities of other lithium compounds are important to many industries. Lithium chloride and lithium bromide are used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contain lithium hypochlorite, as do dry bleaches for commercial laundries. Lithium metal is used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride is used as a component in fluxes for hard-to-weld metals, such as steel alloys and aluminum.

Prices

Yearend published prices for lithium carbonate, the largest volume lithium compound, were unchanged in 1996. Actual prices paid by customers, however, were believed to be significantly lower owing to the December entrance of a second Chilean producer into the lithium carbonate market with the capability of producing large quantities of low-cost carbonate at its operation. Lithium hydroxide monohydrate decreased about 5%, and technical-grade lithium metal increased about 4%. Price changes varied by compound, but overall, prices were stable. *(See table 2.)*

Foreign Trade

Total U.S. exports of lithium compounds were nearly 16% higher in 1996 than in 1995. About 64% of all U.S. exports of lithium compounds were to Germany, Japan, and the United Kingdom.

Imports of lithium compounds decreased 22%. Chile accounted for 92% of all imports, and virtually all the Chilean imports came from Cyprus Foote's operation. Lithium ore concentrates from Australia, Canada, and Zimbabwe were believed to have been consumed in the United States, but no import statistics were available. *(See tables 3 and 4.)*

World Review

A small number of countries throughout the world produced lithium ore and brine. Chile and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and ore concentrates also were produced in Australia, Canada, Chile, China, Portugal, Russia, and Zimbabwe. Argentina, Brazil, and Namibia produced smaller quantities, primarily concentrates. Rwanda, South Africa, and Zaire are past producers of concentrates. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Argentina, Bolivia, China, and Israel. Companies in France, Germany, Japan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Argentina.—FMC progressed in its construction of a lithium brine operation on the Salar de Hombre Muerto in the Argentine Andes. A proprietary selective purification process developed by FMC reduces the number of steps required to recover lithium chloride from the brine and reduces the cost of production compared with other lithium brine operations. A lithium carbonate plant also will operate at the site, and lithium chloride and lithium carbonate will be produced. Capacity is expected to be about 20,000 tons of lithium carbonate equivalent (Kendall, 1997, p. 51). FMC expects the Argentine operation to be completed in 1997, and reserves at the Salar should last at least 75 years at design capacity (FMC Corp., 1997, p. 14).

Australia.—Gwalia Consolidated Ltd., the only lithium ore

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concentrate producer in Australia and the largest in the world, was building a lithium carbonate plant at its spodumene mine at Greenbushes, Western Australia. The plant was expected to begin production in 1996 at a level of 1,000 tons per year lithium carbonate, with a design capacity of 5,000. Technical problems delayed expanded production and full capacity may not be reached until sometime in 1999 (Platt's Metals Week, 1996).

Canada.—The continued interest in lithium batteries and the potential growth of the industry if electric vehicles are powered by lithium batteries have prompted Lithos Corp. of Montreal to explore the possibility of producing lithium metal from lithium deposits in Quebec. Lithos sponsored a research project to develop a low-cost process for producing lithium metal from lithium carbonate and lithium chloride. Electricity prices in Quebec are lower than anywhere in North America, and the low-cost electricity will be instrumental in developing the process (Lithos Corp., 1996a).

The company announced plans at midyear to build a pilot plant to produce 20 to 30 tons of lithium metal per year. Lithos plans to commercialize its patented process for converting lithium carbonate to metal and eventually to produce 200 to 300 tons per year (Lithos Corp., 1996b). Initial production will be based upon purchased lithium carbonate because Lithos has not developed its lithium deposits or built a lithium carbonate plant.

Chile.—Sociedad Quimica y Minera de Chile, a Chilean fertilizer producer, completed development of the second phase of its project on the Salar de Atacama, known as Minsal S.A. The first stage was to produce raw material to supply its potassium nitrate plant. The lithium carbonate portion of the operation began continuous production in November and shipped its first commercial product at the end of 1996 from its plant in Antofagasta (Minsal S.A., 1996).

Minsal announced plans to enter the lithium carbonate market and offered lithium carbonate at $1.98 per kilogram ($0.90 per pound), less than half the Cyprus Foote and FMC prices listed at the time of the announcement. Production rates were expected to expand rapidly to reach more than 18,000 tons. The company expects significantly lower prices to help the company establish market share. Lower prices could lead to an increase in demand for lithium products in new uses for which the cost of lithium compounds has been prohibitive, resulting in enlarged markets for lithium products from all producers (McCoy, 1996, p. 5, 23).

Cyprus Foote began operating a lithium brine project on the same deposit in 1984. The company reported production of 14,000 tons of lithium from its lithium carbonate plant, also in Antofagasta, in 1996 (Cyprus Amax Minerals Co., 1997, p. 13). When both of these operations reach production capacity, Chile should surpass the United States as the world leader in lithium production in all forms.

China.—Details on lithium carbonate production were available for the first time in 1996 and are included in table 5. Lithium carbonate is produced at 13 small plants in 6 provinces (Henan, Hunan, Jiang Su, Jiangxi, Sichuan, and Xinjiang). The lithium carbonate is produced at a large number of small-capacity plants. The largest plant has the capacity to produce 8,000 tons per year, and 10 plants are capable of producing less than 2,000 tons per year. The lithium carbonate plants are reported to use spodumene from deposits in Xinjiang and Sichuan Provinces and lepidolite from Jiangxi Province. Gwalia's spodumene concentrates from Australia also are being used at some of these plants; and Chinese ceramics and glass producers use spodumene concentrates from Gwalia. Chinese lithium is consumed in the following industries: ceramics and glass, 30%; aluminum, 13%; air conditioning, 10%; miscellaneous chemicals, 9%; chemical manufacture, 9%; lubricants, 8%; and batteries, less than 1%. About 20% of China's lithium production is exported.

New Zealand.—Pacific Lithium Ltd. of Aukland, New Zealand, reached a long-term agreement with Toxco to purchase most of Toxco's lithium salts from its Trail, British Columbia, operation and much of the lithium hydroxide monohydrate Toxco acquired from DOE. Pacific Lithium will convert the Toxco material to high-grade lithium carbonate that will then be used in various forms for lithium batteries (Toxco Waste Management Ltd., 1997). Pacific Lithium also is developing a process for adsorbing and processing lithium contained in geothermal brines and seawater. If successful, this process would greatly expand the lithium resources worldwide (Pacific Lithium Ltd., 1997, p. 2).

Outlook

The health of the lithium industry continues to be closely tied to the performance of the primary aluminum industry, the ceramics and glass industry, and the economy in general. Changes in consumption of lithium in these industries determines the performance of the entire lithium industry. Because these uses represent such a high percentage of the total lithium market, growth in other areas has a much smaller influence. Demand for N-butyllithium is expected to continue to increase, and domestic producers have increased production capacity to meet that demand. Demand for lithium metal for batteries and to some extent for alloys should increase, but total consumption of metal will remain low in comparison with the demand for lithium compounds.

Lithium ion batteries, containing lithium in a form other than metal, appear to possess the greatest potential for growth for the entire lithium industry. Lithium ion battery sales in Japan surpassed those of nickel cadmium batteries for the first time in 1996 as a result of the increased popularity of mobile telephones, portable computers, and other consumer electronic products (Matsushita Battery Industry Co. Ltd., 1996). Indications are that major battery producers are confident enough in the success of their research that they have begun to investigate the available supply of lithium raw materials.

Other markets should remain stable with slight growth. Lithium demand could increase dramatically if the technology for nuclear fusion were perfected. This is not expected to occur within the remainder of this century, probably not within the next 25 years, and perhaps never.

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New uses of lithium in the remediation of premature deterioration of concrete through alkali silica reactivity could present another large market for lithium compounds; it may, however, take a few years for lithium hydroxide monohydrate additions to become common, if at all. Other uses of lithium to combat structural deterioration of concrete also are being investigated, but it is too early to predict if these new uses will ever become a significant market.

Chile should overtake the United States as the largest producer of lithium carbonate in 1997, if the Minsal operation reaches full capacity. In addition, when FMC's Argentine operation is phased in and its North Carolina mine is phased out, South America will become the predominant lithium production area in the world.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT LITHIUM STATISTICS 1/

(Metric tons of contained lithium)

	1992	1993	1994	1995	1996
United States:					
Production	W	W	W	W	W
Producers' stock changes	W	W	W	W	W
Imports 2/	770	810	851	1,140	884
Exports 2/	2,100	1,700	1,700	1,900	2,200
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,300	2,300	2,500	2,600	2,700
Rest of world: Production 3/	6,860 r/	7,250 r/	7,360 r/	9,900 r/	11,500 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits.

2/ Compounds.

3/ Mineral concentrate and carbonate.

TABLE 2
DOMESTIC YEAREND PRODUCERS' AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

	1995		1996	
	Dollars per pound	Dollars per kilogram	Dollars per pound	Dollars per kilogram
Lithium bromide, 54% brine: Truckload lots, delivered in drums	5.79	12.75	6.06	13.35
Lithium carbonate, technical: Truckload lots, delivered	1.97	4.34	1.97	4.34
Lithium chloride, anhydrous, purfied: Truckload lots, delivered	3.93	8.66	5.13	11.30
Lithium fluoride	7.70	16.96	7.70	16.96
Lithium hydroxide monohydrate: Truckload lots, delivered	2.55	5.62	2.50	5.51
Lithium metal ingot, battery grade: 1,000-pound lots, delivered	45.95	101.21	NA	NA
Lithium metal ingot, technical grade: 1,000-pound lots, delivered	39.05	86.01	40.60	89.43
N-butylithium in n-hexane (15%): Truckload lots, delivered	20.20	44.49	20.40	44.93

NA Not available.

Source: U.S. lithium producers.

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TABLE 3
U. S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY 1/

Compound and country	1995 Gross weight (metric tons)	1995 Value (thousands)	1996 Gross weight (metric tons)	1996 Value (thousands)
Lithium carbonate:				
Australia	69	$314	80	$367
Belgium	--	--	60	213
Canada	783	2,850	1,100	2,860
France	--	--	73	221
Germany	928	2,970	1,460	4,520
India	114	450	44	172
Japan	2,190	7,690	2,700	10,500
Korea, Republic of	138	468	84	289
Mexico	89	348	189	697
Netherlands	341	1,240	493	1,710
Taiwan	--	--	75	276
United Kingdom	963	2,860	1,290	4,580
Venezuela	196	385	1	4
Other	230	1,090	225	815
Total	6,040	20,700	7,870	28,200
Lithium carbonate U.S.P.: 2/				
Argentina	--	--	3	10
Colombia	24	28	--	--
Dominican Republic	5	6	--	--
Hong Kong	10	20	--	--
India	--	--	10	38
Japan	22	141	(3/)	7
Mexico	11	22	--	--
United Kingdom	25	365	2	153
Venezuela	409	1,000	--	--
Other	6	208	1	12
Total	512	1,790	16	220
Lithium hydroxide:				
Argentina	100	427	76	320
Australia	92	390	149	660
Canada	114	537	117	476
Chile	--	--	121	424
Germany	682	2,770	981	3,720
India	573	2,180	353	1,400
Japan	933	4,270	1,100	5,350
Korea, Republic of	266	1,240	240	1,040
Mexico	176	685	137	555
Philippines	--	--	65	318
Singapore	149	667	82	362
Thailand	135	618	138	604
United Kingdom	373	1,200	356	1,470
Other	461	2,440	469	2,250
Total	4,060	17,400	4,390	18,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Pharmaceutical-grade lithium carbonate.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 4
U. S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS 1/

Compounds	1995 Quantity (metric tons)	1995 Value 2/ (thousands)	1996 Quantity (metric tons)	1996 Value 2/ (thousands)
Lithium carbonate:				
Chile	5,860	$16,500	4,330	$11,700
China	71	251	72	245
Hong Kong	34	126	--	--
Japan	--	--	8	47
Switzerland	--	--	180	510
Other	2	25	1	12
Total	5,970	16,900	4,590	12,500
Lithium hydroxide:				
China	83	328	108	449
Japan	17	216	15	898
Switzerland	--	--	1	38
Other	4	49	2	54
Total	104	593	126	1,440

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Customs value.

Source: Bureau of the Census.

TABLE 5
LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina, spodumene and amblygonite e/	620 4/	300	400	400	400
Australia, spodumene	42,516	52,900 e/	45,987 r/	81,841 r/	117,944 4/
Brazil, concentrates e/	1,600	1,600	1,600	1,600	1,600
Canada, spodumene e/ 5/	18,500	18,900	20,000	21,000	22,000
Chile, carbonate from subsurface brine	10,823	10,369	10,439	14,000 r/	14,500
China, carbonate e/	7,220 r/	8,250 r/	9,050 r/	12,800 r/	15,000
Namibia, concentrates, chiefly petalite	1,162	742	1,861	2,611	2,400
Portugal, lepidolite	15,904 r/	13,289 r/	11,352 r/	10,000 r/ e/	8,000
Russia (minerals not specified) e/ 6/	45,000	40,000	40,000	40,000	40,000
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe (minerals not specified)	12,837	18,064	25,279	26,000 e/	25,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Estimated data are rounded to three significant digits.
2/ Table includes data available through Mar. 31, 1997.
3/ In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported, and no valid basis is available for estimating production levels.
4/ Reported figure.
5/ Based on all of Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).
6/ These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.

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MAGNESIUM

By Deborah A. Kramer

World oversupply of magnesium in 1996 led to a sharp decline in prices throughout the year. As a result of this oversupply, production in the United States declined in 1996. Despite the antidumping duties assessed on Russia, it continued to be the largest import source of primary magnesium. Canada, which was assessed antidumping and countervailing duties, was the largest import source of alloy magnesium. For the first time in 20 years, the United States imported more magnesium than it exported.

Automotive applications continued to dominate new applications for magnesium. Automotive manufacturers introduced several new magnesium components in their 1996 and 1997 models and planned additional components in the coming model years. Because of the wide price swings of magnesium, however, some automakers reversed plans to use magnesium in some applications.

A new primary magnesium plant in Israel produced its first magnesium ingot near the end of 1996. After completing routine shakedown procedures, the plant should be operating at its 27,500-metric-ton-per-year capacity in 1997. Plans continue to construct new primary magnesium plants in Australia, Canada, and Iceland. The Icelandic facility is expected to be completed by 1999; the Canadian facility, by 2000; and the Australian plant, by 2002. When the three plants are operational, they are expected to add 168,000 tons to world annual production capacity.

Legislation and Government Programs

Several changes to the antidumping and countervailing duties assessed on magnesium and magnesium alloy imports from Norsk Hydro Canada Inc. were announced during 1996. Two preliminary countervailing duty determinations were announced by the International Trade Administration (ITA) as a result of administrative reviews. For the period December 6, 1991, to December 31, 1992, countervailing duties for pure and alloy magnesium from Norsk Hydro Canada would be increased to 9.87% ad valorem from the current level of 7.61% ad valorem (U.S. Department of Commerce, 1996c). A preliminary review of countervailing duties on pure and alloy magnesium imports from Canada resulted in the determination of a rate of 4.01% ad valorem for the 1994 calendar year (U.S. Department of Commerce, 1996d). Final results of these reviews were not completed by yearend.

The ITA also issued final determinations on its antidumping order on imports of pure magnesium from Canada as a result of administrative reviews. For the period August 1, 1994, to July 31, 1995, the ITA determined that the weighted average dumping margin for magnesium imports from Norsk Hydro Canada was 0%. This deposit rate will be effective for all pure magnesium imported into the United States from Norsk Hydro Canada after August 12, 1996, the publication date of the final results (U.S. Department of Commerce, 1996e). Because there were no sales of magnesium for the period February 20, 1992, to July 31, 1993, the ITA could not assess separate dumping rates for this period, and the dumping margin of 0% that was established in August was applied to this period (U.S. Department of Commerce, 1996f).

The ITA received requests to conduct administrative reviews of the antidumping and countervailing duties on pure magnesium from Canada covering the period August 1, 1995, to July 31, 1996. The investigation was initiated in September, and final results of this review were scheduled for no later than August 31, 1997 (U.S. Department of Commerce, 1996b).

The ITA offered an opportunity for interested parties to request an administrative review of magnesium imported from China, Russia, and Ukraine. The period covered under the request was November 7, 1994, to April 30, 1996 (U.S. Department of Commerce, 1996a).

Taiyuan Heavy Machinery Import and Export Corp. of China requested a new shipper administrative review of the antidumping duty order on pure magnesium from China. Taiyuan maintains that it did not export magnesium to the United States during the period of investigation, and that it is not affiliated with any producer that did export magnesium during the period of investigation. Commerce is initiating the requested review and will issue final results no later than the end of September 1997 (U.S. Department of Commerce, 1996g).

Production

U.S. primary magnesium production declined by about 6% from 1995 production. World magnesium oversupply and high prices were primarily responsible for the production decrease. Capacity utilization was about 91%. *(See tables 1 and 2.)*

Consumption

Reported consumption of primary magnesium decreased in 1996, mainly because of a drop in demand for magnesium used in aluminum alloying. Aluminum alloying remained the largest end-use application for magnesium, however, representing 51% of total reported primary consumption; this percentage has been decreasing over the last few years as structural applications continue to grow. Structural uses, mostly diecasting, accounted for 24% of total reported consumption. *(See tables 3 and 4.)*

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Use of magnesium alloys in automotive applications continued to grow in 1996. The 1997 model year cars were estimated to contain an average of 2.9 kilograms per vehicle, an increase of 16% from the 1996 level of 2.5 kilograms. New applications in the 1997 model year included instrument panel support beams in some General Motors Corp. (GM) luxury sedans, seat back frames in some GM minivans, and steering column support brackets in some GM and Chrysler Corp. sedans.

In October, Diemakers Inc. reportedly installed the first of two 1,200-ton, cold-chamber diecasting machines at its new facility in Hannibal, MO. Production at the plant was expected to begin in the first quarter of 1997, about 3 months earlier than originally scheduled, because of several new automotive diecasting jobs (Platt's Metals Week, 1996c).

Ganton Technologies reportedly began construction of a new magnesium diecasting facility in Pulaski, TN. The first phase of construction, begun near yearend, was expected to be completed in April 1997, with commercial production beginning in October. Growth in automotive diecasting was cited as the reason for constructing the new plant (Metal Bulletin, 1996b).

Spectrulite Consortium, through a joint venture with Resource Recycling Inc., planned to build a 17,000-ton-per-year nonferrous metals recycling facility in Foley, AL. The joint venture, called Cherokee Metal Recycling, planned to process mixed magnesium alloys, oily scrap, and machine chips, as well as magnesium and aluminum drosses. In addition, the company has purchased a casting line from the defunct Magnesium Co. of Canada plant, which will give Cherokee the capability to produce 4,500 tons of magnesium alloy anodes annually. Construction of the plant began in April (Platt's Metals Week, 1996l).

In July, Garfield Alloys Inc. announced that it would build a new magnesium recycling facility in Bellvue, OH, with a total annual capacity of 13,600 tons. The company already operates a 9,100-ton-per-year recycling plant near Cleveland, which it is in the process of expanding to 13,500 tons per year. The new plant, which was scheduled to be in operation by the second quarter of 1997, will operate under the name MagReTech Inc. and will process clean Type I magnesium scrap only. The facility should have the potential to double its capacity if conditions warrant (Platt's Metals Week, 1996m). Spectrulite also was continuing its efforts to increase recycling capacity at its Madison, IL, plant. The company has added 8,000 tons of annual capacity by installing new equipment and planned to increase annual output by 18,000 tons by the end of 1998 (Metal Bulletin, 1996c). Garfield Alloys and Spectrulite are installing new capacity in response to increased scrap generation by the diecasting industry. Spectrulite estimated that the scrap generation rate for diecasting operations was 40% to 50%.

In June, GM announced that it had signed a long-term contract with Norsk Hydro S.A. to supply GM with its magnesium alloy needs. Although contract terms were not disclosed, the quantity of magnesium alloys was significant, and the contract will extend well into the next decade. Norsk Hydro will supply the magnesium alloys, principally AM60, but also AZ91, to diecasters that are producing parts for GM at a price that is fixed for a 1-year period. Each year, the pricing will be renegotiated. This is the second long-term contract between an automotive manufacturer and a magnesium production firm (the other was Volkswagen and Dead Sea Magnesium in 1995) indicating that automotive manufacturers are committed to maintaining or increasing the quantity of magnesium in these applications (Platt's Metals Week, 1996f).

In February, Ford Motor Co. announced that it would use a urethane-covered magnesium armature for the steering wheels of its redesigned F-series pickup trucks, standard-size sports-utility vehicles, and Econoline vans. The magnesium alloy steering wheels, developed by United Technologies Automotive, will be about one-half of the weight of the steel components that they replace (American Metal Market, 1996).

GM chose magnesium alloy components for two new applications—seats in some 1997 model minivans and battery cases for the company's new electric vehicles. Die-cast magnesium alloy AM60 was chosen as the material for GM's minivan seat back frames and seat bottoms, which will require about 1,400 tons of magnesium annually. Each seat component was expected to weigh between 4.1 and 6.8 kilograms, depending on the minivan model. Meridian Technologies Inc., Toronto, Canada, will be the supplier of the AM60 casting for this application, and Norsk Hydro Canada will be the magnesium source (Wrigley, 1996c). For the battery-case applications, the alloy AZ91D will be molded by a process called Thixomolding, which combines the features of diecasting and injection molding. Although only 2,000 to 3,000 of the electric vehicles will be made annually, magnesium will be used in a number of other components, such as seat frames (Wrigley, 1996b).

Rapidly changing magnesium costs were cited as the reason for two U.S. auto manufacturers to cancel some programs to incorporate more magnesium diecastings into domestic passenger vehicles. Ford decided against switching from steel to magnesium in seat frames for its front-wheel-drive Windstar minivans, which was scheduled to begin with the 1997 models. Conversion of the seat-back frames, and eventually, the seat-bottom frames, was expected to require over 3,600 tons of magnesium diecasting alloy annually. The company also canceled the use of magnesium seat frame bottoms in its low-volume Mustang Cobra model (Wrigley, 1996d). In addition, Ford announced that it would use steel instead of magnesium alloys for the instrument panel support beams in its new luxury sport sedans, scheduled for introduction in 1999 (Wrigley, 1996a). GM decided against switching from aluminum to magnesium in some of its transmission cases. GM said that it could achieve a weight reduction similar to that from magnesium substitution by designing aluminum cases with thinner wall sections than normal (Wrigley, 1997).

Data for magnesium metal are collected from two voluntary surveys of U.S. operations. Of the 94 companies canvassed for magnesium consumption data, 61% responded, representing 55% of the primary magnesium consumption shown in tables 1 and 3. Data for the 33 nonrespondents were estimated based on prior-year consumption levels and other factors.

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Stocks

Producers' yearend 1996 stocks of primary magnesium increased to 17,400 tons from the yearend 1995 level of 12,100 tons. This represents about 1.5 months of production at 1996 rates. Consumer stocks of primary and alloy magnesium increased slightly to 8,720 tons at yearend 1996; the 1995 yearend stocks were 8,700 tons (revised). Yearend 1996 consumer stocks of secondary magnesium declined to 572 tons from the 1995 level of 613 tons.

Prices

Primary magnesium prices dropped throughout 1996 mainly because of an oversupply of material to the world market. The sharpest decline occurred during the first 4 months of the year when the free market price dropped by about $1,000 per ton. At the beginning of 1996, the Metal Bulletin free market price range was $4,075 to $4,200 per ton; by yearend this range had fallen to $2,400 to $2,650 per ton. Other quoted prices followed similar patterns. The Platt's Metals Week European free market price range declined from $4,150 to $4,250 per ton at the beginning of 1996 to $2,600 to $2,700 per ton by yearend. As quoted throughout the year by Platt's Metals Week, the U.S. spot Western price range declined from $1.93 to $2.25 per pound at the start of the year to $1.70 to $1.80 per pound by yearend, and the U.S. spot dealer import price range declined from $2.18 to $2.22 per pound to $1.43 to $1.48 per pound by yearend.

Despite the drop in transaction prices, the U.S. producers did not lower their list prices for primary magnesium until near yearend. In December, Magnesium Corp. of America (MagCorp) announced that it was lowering its list price from $1.93 per pound to $1.80 per pound, effective January 1, 1997. Later, Dow Magnesium matched MagCorp's price reduction, also effective January 1, 1997. Both U.S. producers maintained a price quotation of $1.70 per pound for diecasting alloy AZ91D throughout 1996, although they were offering an 8-cent-per-pound discount on the material (Ozols, 1996).

Foreign Trade

Magnesium exports in 1996 were slightly higher than those in 1995 with most of the increase in scrap exports to Canada. Some of this increase was offset by a drop in exports of primary metal. Imports of magnesium in 1996 increased by 34% from the 1995 level. Imports of primary magnesium were almost three times greater and alloy imports were about 1.5 times as large as imports in 1995. Canada (52%) and Russia (33%) were the principal import sources; imports from Canada were mostly in the form of alloy, and imports from Russia were mostly primary metal. *(See tables 5 and 6.)*

World Review

The United States continued to lead the world in production and production capacity of primary magnesium, with about 39% of the world production, and about 28% of total world capacity. *(See tables 7, 8, and 9.)* Several sources report conflicting figures for China's magnesium production in 1995, ranging from about 12,000 tons to more than 90,000 tons. The 12,000-ton figure most likely counts production from the country's three largest smelters only; many small magnesium production plants (less than 200-ton annual capacity) operate intermittently. Much of China's magnesium production is exported to Japan; this was estimated to be about 40,000 tons in 1995. Production was most likely in the 60,000-ton-per-year range, with the production not exported remaining in stockpiles. Information conflicts regarding China's magnesium production capacity as well. This also stems from the small magnesium plants. Because they operate intermittently and production is used locally, capacity of and production from these plants is not well documented. Sources have published figure as high as 200,000 tons per year as China's annual production capacity.

Oversupply of magnesium affected stock levels throughout the world. According to the International Magnesium Association, 1996 yearend stocks for world producers were 42,100 tons, nearly double the 1995 level of 22,800 tons. World primary magnesium shipments of 295,400 tons were 3% less than those in 1995, with increases in shipments for diecasting and desulfurization offset by declines in shipments for aluminum alloying (International Magnesium Association, 1997).

The European Commission (EC) extended a provisional antidumping decision through the end of June 1996 that imposed minimum prices on magnesium imported from Russia and Ukraine. Minimum import prices of $3,365 per ton for Russian magnesium and $3,315 per ton for Ukrainian magnesium were in effect since December 1995. A delegation from one of the Russian producers and some traders went to Brussels, Belgium, in March 1996 to request that the minimum prices be reduced and that they would be given a quota beneath the floor price so they could import some magnesium into the EC (Platt's Metals Week, 1996d).

Despite a lapse in the provisional decision, the EC retained its antidumping duties on Russian and Ukrainian magnesium imports. However, the duties on both countries' imports were lowered. The minimum import price for Russian magnesium was lowered from 2,735 European Currency Units (ECU) per ton to 2,602 ECU per ton, and the minimum import price on Ukrainian magnesium was lowered from 2,701 ECU per ton to 2,568 ECU per ton (Platt's Metals Week, 1996e). Under terms of an undertaking agreement, however, these duties will be suspended for some imports. Under a clause in the undertaking agreement between the EC, Russia, and Ukraine, specified small quantities of magnesium that are invoiced to a EC-approved importer will not be subject to the duties, even though they are brought in below the minimum value (Platt's Metals Week, 1996i).

Canada.—Norsk Hydro Canada completed a study focused on expanding capacity at its Becancour, Quebec, magnesium facility. The expansion is expected to increase primary

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magnesium production capacity by 10,000 tons per year and alloy capacity by 15,000 tons per year, as market conditions warrant. Alloy expansion increases are expected to be completed by the third quarter of 1997, while no date has been set for primary capacity expansion (Metal Bulletin, 1996d).

Noranda Metallurgy was proceeding with plans to construct a commercial-scale plant to recover magnesium from asbestos tailings in Quebec. Results from 10 months of pilot-plant operation should provide fine tuning for the commercial plant. Noranda also set up a basic engineering study, to be completed by the summer of 1997. Construction of the 58,500-ton-per-year plant was expected to begin in April 1998, to be completed by April 2000 (Metal Bulletin, 1996g).

MSI Magnesium Services Inc. reportedly entered into a joint-venture research program with the Alberta Research Council to develop magnesium recycling technology for its planned 32,000-ton-per-year scrap recovery plant. The C$1.2 million project will cover 4 years and was expected to provide MSI with secondary magnesium production technologies and processes for high-yield recovery of magnesium from scrap (Platt's Metals Week, 1996j).

China.—The Japan-based diecasting company, Nippon Kinzoku, planned to form a joint venture with a Chinese magnesium producer in Sizuishan, Ningxia, to produce magnesium, mainly for export. The joint venture, called Silver River Corp., was scheduled to complete a 1,000-ton-per-year plant by April 1997. Dolomite feed material for the plant will be mined locally, and the plant will be capable of producing 99.8%-pure and 99.9%-pure magnesium. Each of the joint venture partners will be eligible to receive equal portions of the plant's production, even though Nippon Kinzoku will have a 60% holding in the joint venture (Metal Bulletin 1996f). China also was developing magnesium alloys production capacity. Trial quantities of alloys were shipped to Japan to verify standards and quality.

Germany.—The German Government announced the establishment of a $17 million, 3-year magnesium research program to be funded jointly with industry. The program goal is to develop and optimize magnesium alloy products and processes. A total of 57 German companies, including 5 auto manufacturers, are participating in the project (Light Metal Age, 1996).

Iceland.—After completing a feasibility study, officials for the Icelandic Magnesium Project (IMP) said that they would go forward with a planned primary magnesium plant. IMP planned to form a new company, the Icelandic Magnesium Corp., with its partners Salzgitter Anlagenbau GmbH of Germany and Consortium Magniy of the Former Soviet Union. A 50,000-ton-per-year plant, using new technology that does not produce commercial byproduct chlorine, was to be completed in Reykjanes by the second half of 1999. Amalgamet Canada was expected to market primary metal and diecasting alloys that will be produced at the plant (Metal Bulletin, 1996e).

Israel.—Dead Sea Magnesium (DSM) produced the first magnesium ingot on December 14, 1996, from its new plant in Sdom, Israel. After a shakedown procedure that is expected to last until March 1997, full-scale production would begin. The plant, with an annual capacity of 27,500 tons, was scheduled to produce 10,000 tons of magnesium in 1997 (Platt's Metals Week, 1996h). In June 1996, DSM completed a sole-agency deal with Japan's Nissho Iwai to supply the firm with 5,000 tons per year of magnesium beginning in 1997 after the Sdom plant is running at capacity (Metal Bulletin, 1996a).

DSM also was studying plans to construct a magnesium diecasting plant as part of its primary magnesium production facility. Israel's ministry of trade and industry was expected to support the new plant because of high unemployment in the area; estimated employment at the plant would be 100 (Platt's Metals Week, 1996b).

An Israeli diecasting firm, Ortal Diecasting Ltd., signed a memorandum of understanding with Germany's Druckgusswerk Mossner GmbH to construct a $40 million magnesium diecasting plant in Israel. The project, a 50-50 joint venture between the two firms, will produce 4,000 tons per year of magnesium diecastings at a plant at the Neve Ur kibbutz. Completion of the plant is scheduled for 1998 (Platt's Metals Week, 1996g). Ortal Diecasting also signed an agreement with Germany's Audi AG to produce magnesium parts for the auto manufacturer. Ortal's magnesium supplier was expected to be DSM, beginning in 1997. The contract, valued at an estimated $7 million, requires DSM to provide 1,600 tons of magnesium in 1997, increasing to 3,600 tons by 1999 (Platt's Metals Week, 1996k).

Japan.—Japan's magnesium demand reportedly reached 30,500 tons in 1995; the first time that demand exceeded 30,000 tons. The country was totally dependent on imports to supply its primary magnesium requirements, and China, with 17,700 tons, was its largest import source in 1995. Aluminum alloying continued to be the principal use for magnesium in Japan, accounting for about 70% of total demand (Roskill's Letter From Japan, 1996).

Jordan.—The Arab Potash Co. announced plans to construct a new plant to produce magnesium from Dead Sea brines. Arab Potash signed a memorandum of understanding with the Russian Government to construct a 50,000-ton-per-year plant on the Jordanian shore of the Dead Sea. No completion date for the project was scheduled (Platt's Metals Week, 1996a).

United Kingdom.—Alcan Aluminium Ltd. announced the sale of some of its downstream businesses in February. Among the operations that was sold was Magnesium Elektron Ltd., a producer of specialty magnesium alloys. Two plants, one in Swinton, United Kingdom, and the other in Lakehurst, NJ, operating as Reade Manufacturing Co., were included in the sale. The purchasers were a group of institutional investors who will manage the new company under the title British Aluminium Ltd. (Alcan Aluminium Ltd., 1996).

Outlook

Industry analysts expect global use of magnesium diecastings in automotive applications to continue to grow into the next century, with an average annual growth rate of 15% to 20%.

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North America and Europe, not surprisingly, were expected to be the areas with the largest growth. The majority of the growth is expected to fall into six categories of parts—instrument panels and brackets, seat frames, steering column components, manual transmission cases, cylinder head covers, and engine intake manifolds. The principal reasons for the increase in magnesium usage are weight reduction, component consolidation (i.e. fewer individual pieces per component), and competitive cost with the material that magnesium is replacing (Magers, 1996).

With the new magnesium plants being constructed around the world, magnesium supply should keep pace with the growing demand. As is evident from the alliances being formed between auto manufacturers and magnesium producers, automakers are demonstrating a long-term commitment to magnesium.

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TABLE 1
SALIENT MAGNESIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production:					
Primary magnesium	137,000	132,000	128,000	142,000	133,000
Secondary magnesium	57,000	58,900	62,100	65,100	70,900
Exports	52,000	38,800	45,200	38,300	40,500
Imports for consumption	11,800	37,200	29,100	34,800	46,600
Consumption, primary	93,800	101,000	112,000	109,000	102,000
Yearend stocks, producer	5,860	17,800	11,600	12,100	17,400
Price per pound 2/	$1.46-$1.53 3/	$1.43-$1.46	$1.63	$1.93-$2.25	$1.70-$1.80
World: Primary production	295,000	269,000	282,000 r/	389,000 r/	341,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices.

2/ Source: Platt's Metals Week.

3/ Producer price.

TABLE 2
U.S. MAGNESIUM METAL PRODUCERS, BY LOCATION, RAW MATERIAL, AND PRODUCTION CAPACITY IN 1996

Company	Plant location	Raw material	Annual capacity (metric tons)
The Dow Chemical Co.	Freeport, TX	Seawater	65,000
Magnesium Corp. of America	Rowley, UT	Lake brines	40,000
Northwest Alloys Inc.	Addy, WA	Dolomite	40,000
Total			145,000

TABLE 3
MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1995	1996
KIND OF SCRAP		
New scrap:		
Magnesium-base	3,590	8,040
Aluminum-base	31,800	32,800
Total	35,400	40,800
Old scrap:		
Magnesium-base	4,330	4,520
Aluminum-base	25,400	25,600
Total	29,800	30,100
Grand total	65,100	70,900
FORM OF RECOVERY		
Magnesium alloy ingot 2/	W	W
Magnesium alloy castings	2,250	2,750
Magnesium alloy shapes	320	175
Aluminum alloys	58,000	58,800
Zinc and other alloys	10	10
Other 3/	4,570	9,180
Total	65,100	70,900

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes secondary magnesium content of both secondary and primary alloy ingot.

3/ Includes chemical and other dissipative uses and cathodic protection, as well as data indicated by symbol "W."

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TABLE 4
U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE 1/

(Metric tons)

Use	1995	1996
For structural products:		
Castings:		
Die	13,400	14,700
Permanent mold	1,230	1,180
Sand	601	520
Wrought products 2/	8,510	8,080
Total	23,800	24,500
For distributive or sacrificial purposes:		
Aluminum alloys	60,200	52,300
Cathodic protection (anodes)	5,970	5,450
Chemicals	470	331
Iron and steel desulfurization	13,500	13,700
Reducing agent for titanium, zirconium, hafnium, uranium, and beryllium	1,750	2,340
Other 3/	3,460	3,630
Total	85,300	77,800
Grand total	109,000	102,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes extrusions, sheet and plate, and forgings.
3/ Includes nodular iron, scavenger, deoxidizer, and powder.

TABLE 5
U.S. EXPORTS OF MAGNESIUM, BY COUNTRY 1/

	Waste and scrap		Metal		Alloys (gross weight)		Powder, sheets, tubing, ribbons, wire, other forms (gross weight)	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
Australia	--	--	3,000	$8,530	4	$19	19	$125
Belgium	--	--	7,950	17,400	1,540	3,580	2,500	5,820
Canada	3,480	$8,160	221	789	4,000	10,400	921	4,410
Japan	--	--	6,720	20,900	146	785	569	3,610
Korea, Republic of	--	--	111	389	54	556	1,080	1,380
Mexico	--	--	165	597	37	259	1,670	1,040
Netherlands	--	--	2,590	6,090	70	239	38	122
Other	51	194	707	4,540	223	2,490	406	4,000
Total	3,540	8,350	21,500	59,300	6,080	18,400	7,200	20,500
1996:								
Australia	--	--	3,120	9,730	10	45	19	67
Belgium	9	23	2,940	12,200	656	1,670	728	2,260
Canada	8,360	20,500	24	84	4,830	17,500	860	4,880
Japan	6	15	5,410	17,400	123	532	486	4,910
Korea, Republic of	25	64	67	198	18	378	1,140	1,580
Mexico	9	23	373	1,570	36	253	3,180	542
Netherlands	20	45	4,810	13,300	1,100	3,360	902	2,550
Other	67	201	289	2,860	200	2,140	661	3,930
Total	8,500	20,900	17,000	57,300	6,970	25,900	7,970	20,700

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM, BY COUNTRY 1/

Country	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (gross weight)	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
Brazil	--	--	534	$2,390	--	--	--	--
Canada	8,570	$19,300	471	1,740	13,300	$44,700	858	$4,190
China	281	528	384	517	51	88	--	--
Mexico	690	1,190	609	1,470	173	369	3	36
Russia	292	787	4,250	16,100	1,300	3,710	--	--
United Kingdom	318	779	--	--	405	3,050	4	147
Other	1,390	3,420	235 r/	802 r/	661	3,140	1	28
Total	11,500	26,000	6,480	23,000	15,900	55,100	867	4,410
1996:								
Brazil	133	457	717	2,860	36	124	--	--
Canada	1,460	3,230	1,130	4,830	20,900	74,700	1,050	5,460
China	57	131	171	467	1,680	4,540	52	144
Mexico	364	642	521	1,880	193	694	158	602
Russia	--	--	14,400	47,100	1,170	4,470	14	58
United Kingdom	311	666	163	450	363	3,320	2	193
Other	1,020	2,540	219	856	277	1,860	(2/)	7
Total	3,340	7,660	17,300	58,500	24,600	89,700	1,280	6,470

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 7
WORLD ANNUAL PRIMARY MAGNESIUM PRODUCTION CAPACITY, 1/ DECEMBER 31, 1996, BY CONTINENT AND COUNTRY 2/

(Metric tons)

Continent and country	Capacity
North America:	
Canada	49,000
United States	145,000
Total	194,000
South America: Brazil	10,600
Europe:	
France	17,000
Kazakstan 3/	65,000
Norway	35,000
Russia 3/	82,000
Serbia and Montenegro	5,000
Ukraine 3/	54,000
Total	258,000
Asia:	
China	32,400
India	900
Israel	27,500
Total	60,800
World total	523,000

1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes magnesium production capacity that is used exclusively for titanium production as follows: Kazakstan, 40,000 metric tons; Russia, 35,000 metric tons; and Ukraine, 15,000 metric tons.

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TABLE 8
MAGNESIUM: WORLD PRIMARY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Brazil e/	7,300	9,700	9,700	9,700	9,000
Canada e/	25,800	23,000	28,900	48,100	54,000
China e/	10,600	11,800	24,000	93,600 r/	50,000
France	13,660	10,982	12,280	14,450 r/	14,000
Italy	1,211	--	--	--	--
Japan	7,119	7,471	3,412	--	-- 3/
Kazakstan e/	3,000	2,000	--	-- 3/	-- 3/
Norway	30,404	27,300	27,635	28,000 r/	30,000
Russia e/ 4/	40,000	30,000	35,400	37,500	35,000
Serbia and Montenegro	4,055	-- e/	-- r/	2,560 r/	2,500
Ukraine e/	15,000	14,900	12,000	13,000	13,000
United States	137,000	132,000	128,000	142,000	133,000 3/
Total	295,000	269,000	282,000 r/	389,000 r/	341,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 15, 1997.
3/ Reported figure.
4/ Includes secondary.

TABLE 9
MAGNESIUM: WORLD SECONDARY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Brazil e/	1,600	1,600	1,600	1,600	1,600
Japan	12,978	13,215	19,009	11,767 r/	12,500
U.S.S.R. e/ 3/	6,500	6,000	5,000	6,000	6,000
United Kingdom e/ 4/	800	1,000	1,000	1,000	1,000
United States	57,000	58,900	62,100	65,000	70,900 5/
Total	78,900	80,700	88,700	85,500 r/	92,000

e/ Estimated. r/ Revised.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 15, 1997.
3/ Dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries.
4/ Includes alloys.
5/ Reported figure.

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MAGNESIUM COMPOUNDS

By Deborah A. Kramer

Increased use of magnesia in water treatment applications and reduced imports of dead-burned magnesia from China were primarily responsible for the overall increase in U.S. production of magnesium compounds in 1996. Although U.S. production increased, apparent consumption declined; the increase in domestic dead-burned magnesia production did not completely replace the drop in imports of Chinese dead-burned magnesia. China remained the largest U.S. import source of magnesia, but with the export licensing and quota system that was established in 1994, imports in 1996 decreased by more than 100,000 metric tons from the 1995 level. Refractories were the principal use of magnesia in the United States, accounting for 64% of total magnesium compounds consumption. U.S. firms planned to expand production of dead-burned magnesia, and a new magnesium hydroxide plant was completed to help meet demand for this material in water treatment applications.

Production

U.S. production of caustic-calcined magnesia, dead-burned magnesia, and magnesium hydroxide increased in 1996. Increased caustic-calcined magnesia production principally was the result of increased consumption of this material in acid neutralization applications, mostly water treatment. Magnesium hydroxide production increased to supply dead-burned magnesia production and also because of increased usage in water treatment applications. Dead-burned magnesia production increased partially to replace the loss of imported material from China.

Harbison-Walker Refractories Inc. installed a fifth shaft kiln for producing dead-burned magnesia at its Ludington, MI, facility. The new kiln, which was operational in August, will increase the company's total annual production capacity from 150,000 tons to 200,000 tons. Harbison-Walker also is expanding its magnesium hydroxide filtration unit to accommodate the increased production capacity (Industrial Minerals, 1996e).

Martin Marietta Magnesia Specialties Inc. completed a 15,000-ton-per-year magnesium hydroxide plant in Lenoir City, TN, in the fourth quarter. This new plant complements the company's magnesium hydroxide production capacity in Manistee, MI, (80,000 tons per year) and Pittsburgh, PA (30,000 tons per year). The Tennessee and Pennsylvania plants recover magnesium hydroxide from imported Chinese magnesite, while the Michigan plant uses underground brines as a raw material. Magnesium hydroxide produced at the new facility was expected to be used for water treatment (Chemical Market Reporter, 1996). Lockheed Martin Corp., the parent company of Martin Marietta Magnesia Specialties, announced that it would divest its 81% interest in the subsidiary to concentrate on its aerospace and defense markets. In October, Lockheed Martin began an exchange offer that would give shareholders a chance to exchange 4.72 shares of Martin Marietta Materials for 1 share of Lockheed Martin common stock (North American Mineral News, 1996).

Premier Services Corp., the sole magnesite producer in the United States purchased additional mining equipment that the company says will double magnesite mining capacity at its Gabbs, NV, mine. Premier Services produces caustic-calcined and dead-burned magnesia from the mined magnesite using multiple-hearth and rotary kilns. *(See tables 1 and 2.)*

Data for magnesium compounds were collected from one voluntary survey of U.S. operations. Of the 18 operations canvassed, 72% responded, representing 58% of the magnesium compounds shipped and used shown in table 3. Data for the five nonrespondents were estimated based on prior-year consumption levels and other factors. *(See table 3.)*

Two companies in the United States produced olivine—Unimin Corp. and Olivine Corp. Unimin operated two mines, one in North Carolina and one in Washington, and processing plants in Indiana, North Carolina, and Washington; Olivine operated one mine and one processing plant in Washington.

The largest magnesite production facilities in the world are in China, North Korea, and Russia. Together, these three countries account for 60% of the world magnesite production capacity. Japan and the United States account for 57% of the world's magnesium compounds production capacity from seawater or brines. Fused magnesia is produced in Australia, Brazil, Canada, China, France, Israel, Japan, the Republic of Korea, Mexico, the United Kingdom, and the United States. A review of the world fused magnesia industry was published in January (O'Driscoll, 1996).

Norway, the world's principal producer of olivine, supplied its domestic needs and was a major world supplier of olivine. Countries with smaller output included Australia, Italy, Japan, Mexico, Pakistan, Spain, and the United States.

Consumption

In 1996, chemical applications were the dominant use for caustic-calcined magnesia, accounting for 45% of U.S. shipments. The following categories, with the individual components in parentheses in declining order, were the other end-use sectors for caustic-calcined magnesia: metallurgical (water treatment, refractories, and electrical), 27%; agriculture

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(animal feed and fertilizers), 11%; manufacturing (pulp and paper, rubber, fluxes, and fuel additives), 8%; construction (oxychloride and oxysulfate cements and general construction), 4%; pharmaceuticals and nutrition (cosmetics, sugar, candies and other food items, and medicinal and pharmaceutical), 4%; and unspecified uses, 1%. Water treatment continued to exhibit significant market growth; it was the second largest individual use of caustic-calcined magnesia.

Magnesium carbonate was used principally as a chemical intermediate, in rubber processing, and in cosmetics. Magnesium hydroxide was used mainly in the chemical industries and for water treatment. Magnesium sulfate was used mostly in pharmaceuticals and animal feed.

Magnesium chloride was used mainly as a chemical intermediate. Magnesium chloride brines were used principally for refractories and for road dust and ice control.

Foundry uses remained the largest application for olivine in the United States, accounting for 79% of consumption of domestically produced material. Refractory applications accounted for 14% of U.S. demand, sandblasting and other abrasive uses accounted for 6%, and soil conditioners accounted for 1%.

Prices

Yearend magnesium compounds prices quoted in Chemical Marketing Reporter did not change from those at yearend 1995. U.S. olivine prices, quoted in Industrial Minerals, were $62 to $109 per ton for foundry grade and $50 to $78 per ton for aggregate material, the same as price quotes at yearend 1995. All prices were quoted f.o.b. mine or plant. *(See table 4.)*

Foreign Trade

Because of export licensing requirements, U.S. imports of magnesia from China fell for the first time in 7 years; however, China remained the principal import source for caustic-calcined and dead-burned and fused magnesia. *(See tables 5, 6, 7, and 8.)*

Trade data for olivine is not available separately from the Bureau of the Census. The Journal of Commerce Port Import/Export Reporting Service provides data on material that travels by ship. In 1996, the United States exported 488 tons of olivine, with the Republic of Korea (25%) and Chile (25%) as the principal destinations. Olivine imports totaled 176,000 tons of olivine, all from Norway.

World Review

Australia.—Queensland Metals Corp. (QMC) purchased Pancontinental Resources Pty. Ltd.'s 40% ownership of the Queensland Magnesia Project (QMAG) for A$63 million. The deal gives QMC 100% ownership in QMAG. QMC plans to install ore sorting capabilities at the Kunwarara magnesite mine and expand capacity for producing fused and dead-burned magnesia with a A$28 million investment. Production capacity for fused magnesia will be increased by 33% to 40,000 tons per year, and capacity for dead-burned magnesia production will be increased by 50% to 120,000 tons per year. The new capacity was expected to be operational by mid-1997 (Queensland Metals Corp., 1996). In October, QMC completed a 25,000-ton-per-year magnesium hydroxide slurry plant in Melbourne, with ICI Australia, QMC's joint-venture partner, providing one-half of the financing. By yearend, plant trials had begun (Industrial Minerals, 1996a).

Devex Ltd. announced that it would sell Causmag Ore Pty. Ltd., its magnesia subsidiary, to concentrate on its gold mining business. Causmag, which operates caustic-calcined magnesia production facilities in Young, New South Wales, had recently completed a feasibility study for the production of fused magnesia and was planning to build a 10,000-ton-per-year plant. These plans were expected to be unsettled until the sale of Causmag is finalized; at yearend, there were no buyers for the operation (Industrial Minerals, 1996b).

Brazil.—Magnesita S.A., Brazil's largest magnesite producer, was expanding into caustic-calcined magnesia production. The company installed a 30,000-ton-per-year kiln to increase production capacity for caustic-calcined magnesia to 70,000 tons per year; the new kiln is expected to be operational by March 1997. Markets for caustic-calcined magnesia in Brazil include slag control, fertilizers, cement, abrasives, and magnesia salts (Kendall, 1996).

China.—The Chinese Government instituted a set of new policies to combat reported cases of magnesite smuggling, which have been estimated to amount to 200,000 tons to 300,000 tons in a year. The new policies specify specific ports that can export magnesia products and include mineral products containing at least 70% MgO. These policies also are designed to question exports that are designated by other mineral names, such as wollastonite, dolomite, and brucite. Illegal exports of magnesite, as well as bauxite and fluorspar, are occurring because of the export licensing procedures (Industrial Minerals, 1996c). In November, the Chinese Government issued a list of 18 companies that have negotiated bidding rights for magnesite export licenses for 1997 and specified the official export quota for 1997 as 2 million tons (Industrial Minerals, 1996d).

France.—Pechiney Electrometallurgie announced that it would discontinue production of fused magnesia and fused spinel by the end of April 1996 (Industrial Minerals, 1996g). Pechiney operated a 10,000-ton-per-year plant at Chedde, Haute-Savoies, which was under negotiation for acquisition by Universal Ceramic Minerals plc (UCM) of the United Kingdom. In January, UCM announced that the negotiations for the plant were terminated. Pechiney planned to sue UCM for Ffr20 million for undertaking the negotiations in "bad faith." Pechiney claimed that UCM terminated the negotiations after acquiring considerable technical knowledge about the operation at Chedde (Industrial Minerals, 1996h).

India.—An Indian refractories manufacturer announced that it was considering building a 10,000-ton-per-year fused magnesia-alumina spinel plant near existing operations in Bihar. One of the reasons for establishing domestic production of this

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material is the high duties on refractory products; low-value raw materials can be imported more economically. No timetable was established for plant construction (Industrial Minerals, 1996i). Work was continuing on India's first seawater magnesia plant, and Birla Periclase, a subsidiary of Aditya Birla Group Co., expected production to begin by the end of 1996.

Italy.—In January, Sardamag SpA sold its 20% participation in Nuova Sardamag Srl to Sigma Investimenti SpA, a holding company for the Sardinian regional government that owned the remaining 80%. Sardamag operates a 75,000-ton-per-year seawater magnesia plant in Sicily and Nuova Sardamag operates a 60,000-ton-per-year seawater magnesia plant in Sardinia. Sardamag will continue to purchase and resell material produced by Nuova Sardamag (Industrial Minerals, 1996f).

Slovakia.—In March, Greenpeace, the international environmental organization, reportedly was pressuring the Kocise Magnesite State Enterprise to close its calcining operation because of blowing dust from the plant. The plant is due to be replaced by a new facility about 15 kilometers outside Kocise, but the plant would not be ready for commissioning for at least 6 months. The company wanted to keep the older plant operating until the new one was ready, but the environmental group felt that this was too long (Industrial Minerals, 1996k).

United Kingdom.—UCM announced plans to expand its fused magnesia plant at Hull. By the end of the fourth quarter, the company expected to commission a 12,000-ton-per-year expansion to its subsidiary Electro Furnace Products Ltd. With closures in France and Germany in 1996, UCM was strengthening its position as the world largest fused magnesia producer. With the additional capacity, UCM's total annual capacity will be about 37,000 tons, including capacity from a plant in the United States (Industrial Minerals, 1996j). *(See tables 9 and 10.)*

Outlook

With the reduced supplies of dead-burned magnesia from China and capacity expansions at U.S. plants, domestic production of dead-burned magnesia is likely to increase in the next few years. Continued strong demand for magnesium hydroxide and caustic-calcined magnesia for acid neutralization applications is likely to boost domestic production of these materials as well. Overall consumption of magnesium compounds is expected to remain at about the same level as 1996, but demand for magnesia for uses other than refractories is expected to grow; therefore, refractories, while still the largest end use for magnesia, are expected to reflect a smaller percentage of the total market.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT MAGNESIUM COMPOUND STATISTICS 1/

(Thousand metric tons, unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Caustic-calcined and specified magnesias: 2/						
Shipped by producers: 3/						
Quantity		130	131	135	141	158
Value	thousands	$36,800	$39,500	$39,300	$37,900	$47,600
Exports 4/		5	4	3	2	20
Imports for consumption 4/		83	141	125	139	114
Refractory magnesia:						
Shipped by producers: 3/						
Quantity		291	268	243	234	269
Value	thousands	$80,800	$77,700	$67,800	$83,800	$96,800
Exports		57	60	60	75	73
Imports for consumption		210	279	342	393	271
Dead-burned dolomite:						
Sold and used by producers:						
Quantity		302	315	300	308	NA
Value	thousands	$25,200	$26,200	$25,000	$28,100	NA
World production (magnesite)		10,200 r/	8,280 r/	8,720 r/	9,940 r/	9,170 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits.

2/ Excludes caustic-calcined magnesia used in the production of refractory magnesia.

3/ Includes magnesia used by producers.

4/ Caustic-calcined magnesia only.

TABLE 2
U.S. MAGNESIUM COMPOUND PRODUCERS, BY RAW MATERIAL SOURCE, LOCATION, AND PRODUCTION CAPACITY, IN 1996

Raw material source and producing company	Location	Capacity (metric tons of MgO equivalent) 1/	Products
Magnesite: Premier Services Inc.	Gabbs, NV	100,000	Caustic-calcined and dead-burned magnesia.
Lake brines:			
Great Salt Lake Minerals Corp.	Ogden, UT	106,000	Magnesium chloride and magnesium chloride brines.
Reilly Industries Inc.	Wendover, UT	45,000	Magnesium chloride brines.
Well brines:			
The Dow Chemical Co. 2/	Ludington, MI	214,000	Magnesium hydroxide.
Martin Marietta Magnesia Specialties Inc. 3/	Manistee, MI	275,000	Caustic-calcined and dead-burned magnesia.
Morton International	do.	10,000	Magnesium carbonate, magnesium hydroxide, and caustic-calcined magnesia.
Seawater:			
Barcroft Co.	Lewes, DE	5,000	Magnesium hydroxide.
The Dow Chemical Co.	Freeport, TX	20,000	Magnesium chloride.
National Refractories & Minerals Corp.	Moss Landing, CA	165,000	Magnesium hydroxide and caustic-calcined and dead-burned magnesia.
Premier Services Inc.	Port St. Joe, FL	50,000	Caustic-calcined and dead-burned magnesia.
Total		990,000	

1/ Data are rounded to three significant digits; may not add to total shown.

2/ Most of Dow's production is shipped to Harbison-Walker Refractories Co. in Ludington, MI, where it is converted to dead-burned magnesia at a 200,000-ton-per-year plant.

3/ In addition to its Michigan plant, Martin Marietta owns a 30,000-ton-per-year magnesium hydroxide plant in Pittsburgh, PA, and a 15,000-ton-per-year magnesium hydroxide plant in Lenoir City, TN, which use imported magnesite as a raw material.

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TABLE 3
U.S. MAGNESIUM COMPOUNDS SHIPPED AND USED 1/

	1995		1996	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined 2/ and specified (USP and technical) magnesias	141,000	$37,900	158,000	$47,600
Magnesium hydroxide [100% Mg (OH)2] 2/	297,000	98,800	338,000	112,000
Magnesium sulfate (anhydrous and hydrous)	46,100	19,800	45,600	19,500
Precipitated magnesium carbonate 2/	3,070	735	2,960	726
Refractory magnesia	234,000	83,800	269,000	96,800

1/ Data are rounded to three significant digits.
2/ Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

TABLE 4
YEAREND MAGNESIUM COMPOUND PRICES

Material		Price
Magnesia, natural, technical, heavy, 85%, f.o.b. Nevada	per short ton	$232- $265
Magnesia, natural, technical, heavy, 90%, f.o.b. Nevada	do.	265
Magnesia, dead-burned	do.	330
Magnesia, synthetic, technical	do.	366
Magnesium chloride, hydrous, 99%, flake	do.	290
Magnesium carbonate, light, technical, freight equalized	per pound	.73- .78
Magnesium sulfate, technical, epsom salts	do.	.16

Source: Chemical Marketing Reporter.

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TABLE 5
U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY 1/

Material and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Caustic-calcined magnesia:				
France	107	$72	1,480	$1,070
Germany	302	166	14,300	4,360
Mexico	672	283	1,220	340
Netherlands	882	475	690	379
Spain	--	--	1,700	510
Other	316 r/	199 r/	208	113
Total	2,280	1,200	19,600	6,770
Dead-burned and fused magnesia:				
Canada	46,800	17,200	42,500	15,600
Germany	8,390	3,320	8,890	2,750
Netherlands	4,920	1,490	7,190	2,300
Switzerland	--	--	5,520	1,660
United Kingdom	6,510	2,630	2,180	1,220
Venezuela	4,120	1,360	2,910	945
Other	4,030	2,570	3,380	3,040
Total	74,800	28,600	72,600	27,500
Other magnesia:				
Canada	4,790	2,310	5,450	2,640
China	398	244	1,320	480
Colombia	193	320	1,450	539
Mexico	608	739	2,680	1,770
Spain	420	495	1,050	1,320
United Kingdom	84	103	1,470	1,870
Venezuela	3,130	988	--	--
Other	2,750 r/	3,110 r/	3,130	3,910
Total	12,400	8,300	16,600	12,500
Crude magnesite:				
Brazil	6,000	642	5,220	558
Canada	1,990	433	1,040	258
France	30	3	4,390	623
Germany	2,490	547	1,580	342
Korea, Republic of	6,620	716	5,340	621
Mexico	1,170	140	5,000	586
Venezuela	4,450	585	5,170	587
Other	9,160 r/	1,060 r/	5,270	669
Total	31,900	4,120	33,000	4,240

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 6
U.S. EXPORTS OF MAGNESIUM COMPOUNDS 1/

Material	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Magnesium chloride, anhydrous and other	3,060	$1,700	3,630	$2,750
Magnesium hydroxide and peroxide	17,400	6,010	12,200	6,560
Magnesium sulfate, natural kieserite and epsom salts	1,830	294	6,750	877
Magnesium sulfate, other	4,740	1,830	5,030	1,810

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY 1/

Material and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Caustic-calcined magnesia:				
Canada	37,100	$7,310	37,300	$7,810
China	96,700	11,700	63,700	6,870
Greece	4,050	947	10,500	2,580
Other	843	1,250	2,700	1,940
Total	139,000	21,200	114,000	19,200
Dead-burned and fused magnesia:				
Australia	18,000	5,220	12,100	3,620
Austria	19,300	8,590	21,000	9,530
Brazil	15,000	1,720	10,000	1,190
China	321,000	46,100	193,000	30,100
Greece	3,310	770	5,710	911
Slovakia	--	--	9,010	1,020
Other	16,300 r/	10,800 r/	20,500	11,300
Total	393,000	73,200	271,000	57,600
Other magnesia:				
China	132	93	2,520	944
Israel	2,380	3,070	2,790	3,450
Japan	1,140	2,230	973	1,810
Mexico	7,530	2,640	4,100	1,570
Other	1,440 r/	1,890 r/	1,470	1,270
Total	12,600	9,930	11,900	9,040
Crude magnesite:				
China	693	294	5,290	441
Greece	3,450	466	153	24
Netherlands	9,080	3,450	3,610	1,370
Other	378 r/	111 r/	129	59
Total	13,600	4,320	9,190	1,900

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM COMPOUNDS 1/

	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Magnesium chloride, anhydrous and other	16,500	$4,780	21,500	$5,600
Magnesium hydroxide and peroxide	4,940	9,550	4,310	7,590
Magnesium sulfate, natural kieserite	27,400	1,510	18,700	1,120
Magnesium sulfate, natural epsom salts	26	31	24	23
Magnesium sulfate, other	16,000	3,360	20,200	4,260

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

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TABLE 9
WORLD MAGNESIUM COMPOUNDS ANNUAL PRODUCTION CAPACITY 1/ 2/
DECEMBER 31, 1996

(Thousand metric tons, MgO equivalent)

Country	Raw material				Total
	Magnesite		Seawater or brines		
	Caustic-calcined	Dead-burned	Caustic-calcined	Dead-burned	
North America:					
Canada	100	--	--	--	100
Mexico	--	--	15	95	110
United States	NA	NA	NA	NA	990 3/
Total	100	NA	15	95	1,200
South America: Brazil	58	291	--	--	349
Europe:					
Austria	80	485	--	--	565
France	--	--	30	--	30
Greece	120	80	--	--	200
Ireland	--	--	--	90	90
Italy	25	--	5	130	160
Netherlands	--	--	--	130	130
Norway	--	--	25	--	25
Poland	--	10	--	--	10
Russia	--	2,220	--	--	2,220
Serbia and Montenegro	40	200	--	--	240
Slovakia	30	275	--	--	305
Spain	140	65	--	--	205
Turkey	50	279	--	--	329
Ukraine	--	120	20	80	220
United Kingdom	--	--	70	80	150
Total	485	3,740	150	510	4,880
Africa:					
Kenya	NA	NA	--	--	170
South Africa	7	--	--	--	7
Total	7	NA	--	--	177
Asia:					
China	200	1,770	--	10	1,980
India	25	246	--	--	271
Iran	--	30	--	--	30
Israel	--	--	10	60	70
Japan	--	--	65	265	330
Korea, North	NA	NA	--	--	500
Korea, Republic of	--	--	--	50	50
Total	225	2,040	75	385	3,230
Oceania: Australia	40	107	--	--	147
Grand total	915	6,180	240	990	9,980

NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes capacity at operating plants as well as at plants on standby basis.

3/ Includes capacity for production of magnesium chloride, magnesium chloride brines, magnesium carbonate, magnesium hydroxide, and caustic-calcined and dead-burned magnesia.

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TABLE 10
MAGNESITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Australia e/	262,000	260,600	286,000 r/	263,000 r/	290,000
Austria	995,347	648,864	681,000	784,000 r/	700,000
Brazil 3/ (beneficiated)	273,014	232,367	279,251 r/	318,745 r/	320,000
Canada e/ 4/	180,000	180,000	180,000	180,000	180,000
China e/	1,510,000	1,230,000	990,000 r/	1,200,000	1,000,000
Colombia	18,840	8,816	10,747	10,000 e/	10,000
Czechoslovakia 5/	1,267,000	XX	XX	XX	XX
Greece	471,200 r/	479,999 r/	575,472 r/	520,000 r/ e/	500,000
India	602,506	408,971	336,735 r/	334,710 r/	335,000
Iran 6/	36,165	49,424	40,000 e/	40,000 e/	40,000
Korea, North e/	1,600,000	1,600,000	1,600,000	1,600,000	1,600,000
Mexico	--	1,530	1,500 e/	1,200 r/ e/	1,300
Pakistan	6,484	4,157	4,464 r/	16,891 r/	17,000
Philippines e/	700	700	700	700	700
Poland	12,900	13,000	16,400	21,500 r/	20,000
Russia e/	1,100,000	800,000	700,000	700,000	600,000
Serbia and Montenegro	185,000	55,000	68,000	75,000 e/	75,000
Slovakia e/ 7/	XX	1,200,000	1,200,000	1,200,000	1,000,000
South Africa	60,085	67,403	71,726 r/	84,289 r/	71,500
Spain e/	400,000	400,000	400,000	400,000	400,000
Turkey (run of mine)	1,224,900	628,782	1,279,614	2,184,681 r/	2,000,000
United States	W	W	W	W	W
Zimbabwe	8,973	6,276	1,588 r/	8,199 r/	8,000
Total	10,200,000 r/	8,280,000 r/	8,720,000 r/	9,940,000 r/	9,170,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." XX Not applicable.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 20, 1997.

3/ Series reflect output of marketable concentrates. Production of crude ore was as follows, in tons: 1992--1,001,724; 1993--974,161; 1994--1,019,688 (revised); 1995--1,230,955 (revised); and 1996--1,200,000 (estimated).

4/ Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

5/ Dissolved on Dec. 31, 1992. All production for Czechoslovakia in 1992 came from Slovakia.

6/ Year beginning Mar. 21 of that stated. Includes 220 tons in 1992 of huntite ($Mg_3Ca(CO_3)_4$), white clay.

7/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

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MANGANESE

By Thomas S. Jones

Manganese (Mn) is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Steelmaking, including its ironmaking component, has accounted for most domestic manganese demand, presently in the range of 85% to 90% of the total. Among a variety of other uses, manganese is a key component of certain widely used aluminum alloys and is used in oxide form in dry cell batteries. The overall level and nature of manganese use in the United States is expected to remain much the same in the near and medium term. Currently, no practical approaches exist for replacing manganese by other materials or for basing U.S. raw material supply on domestic sources, either deposits or other accumulations.

Current ongoing trends in consumption were indicated to be, for steelmaking, some shifting from ferromanganese to silicomanganese and, for dry cell batteries, displacement of natural manganese dioxide by synthetic dioxide, principally electrolytic manganese dioxide (EMD).

U.S. foreign trade in manganese materials was active in 1996. Exports of ore increased significantly. Import volume was up for nearly all material categories, that for silicomanganese to a record high.

The price for metallurgical-grade ore rose (by about 7% on international markets) while prices fell for ferroalloys. January-to-December price decreases for U.S. imports were 14% for ferromanganese and 37% for silicomanganese.

The Government's stockpile disposal program was expanded for manganese to include ferromanganese, to which significant restrictions applied. The rate of disposal of manganese materials was nearly as great as in 1995. The majority of disposals was of ore.

Production of manganese ore was believed for most of the world's main producers to have been at about the same level as in 1995 or possibly even greater. *(See table 1.)* The final total will be more certain once data for China become available. Developments in foreign production of manganese ferroalloys included, in South Africa, establishment of joint ventures between Japanese and South African interests for production of refined and/or specialty grades of ferromanganese and silicomanganese and, in Iran and Saudi Arabia, the startup of new smelters.

Most data in this report are rounded by the U.S. Geological Survey to three significant digits. Table footnotes will indicate which statistics have been rounded.

Legislation and Government Programs

Stockpile.—The Defense Logistics Agency (DLA) modified its Annual Materials Plan (AMP) with respect to manganese by including synthetic manganese dioxide and ferromanganese. With this change, the maximum fiscal year disposal authority for manganese materials became, in metric tons, 54,431 for natural battery-grade ore; 2,732 for synthetic manganese dioxide; 36,287 for chemical-grade ore; 362,874 for metallurgical-grade ore; 45,359 for ferromanganese; and 1,814 for electrolytic manganese metal. These figures for the revised fiscal year 1996 AMP and also the fiscal year 1997 AMP were submitted to Congress on February 15. These AMP's became effective April 1 and October 1, respectively.

Disposals of ferromanganese were required to consist first of material not meeting the stockpile classification of Grade One, as stipulated in the National Defense Authorization Act for fiscal year 1996. This act was a part of Public Law 104-106 that became effective February 10. On August 28, DLA issued Solicitation of Offers DLA-FERROMANGANESE-001 for sale of manganese ferroalloys. Material being offered for sale during the remainder of fiscal year 1996 comprised 42,910 tons of high-carbon ferromanganese, 2,268 tons of medium-carbon ferromanganese, and 181 tons of silicomanganese. Material being offered for sale during fiscal year 1997 comprised 40,823 tons of high-carbon ferromanganese and 4,536 tons of medium-carbon ferromanganese. Many sale conditions were negotiable; long-term contracts for up to 5 years could be considered, and, as specified in Public Law 104-106, sale of high-carbon ferromanganese was restricted to domestic producers of manganese ferroalloys for remelting.

On November 27, DLA canceled Solicitation of Offers DLA-MET-101 for sale of electrolytic manganese metal, and stated that a new solicitation would be issued in 1997.

Disposals of manganese materials in 1996 announced by DLA totaled, in tons, natural battery-grade ore, 7,121; metallurgical-grade ore, 38,501; and electrolytic metal, 2,518. All disposals were cash transactions.

Data on physical inventory of manganese materials reported by DLA indicated that changes in 1996 consisted, in tons, of decreases of 131,298 for metallurgical-grade ore and 2,126 for electrolytic metal, and increases of 3,766 for natural battery-grade ore and 2,169 for high-carbon ferromanganese. The estimated manganese content of the manganese inventories being held by the Government at yearend was lowered 4.1% to somewhat less than 1.4 million tons. *(See table 2.)* Total inventory was still about twice current national apparent consumption.

Other.—The Government continued to encourage limited study of marine mineral resources, including manganese nodules, through enactment of two laws that became effective

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October 19 (Public Law 104-312 and Public Law 104-325). Public Law 104-325 amended the Mining and Minerals Policy Act of 1970 by adding to it a Title II that directed the Secretary of the Interior to conduct a program of research on marine mineral resources. The Secretary also was directed to designate three centers for marine mineral research, the primary areas of concentration of which were to be continental shelf regions, deep seabed and near-shore environments of islands, and arctic and cold water regions, respectively. Public Law 104-312 stated that the amount to be made available for such research should not exceed $1.8 million for each fiscal after fiscal year 1996. Subsequently during 1996, Congress did not appropriate funds for this purpose.

The Mercury-Containing and Rechargeable Battery Management Act (Public Law 104-142, which became effective May 13) prohibited sale in the United States of alkaline manganese or carbon-zinc batteries into which mercury had been introduced intentionally. An exception was that alkaline-manganese button cells could contain up to 25 milligrams of mercury per cell. Title I of this act excluded rechargeable alkaline batteries from requirements imposed on other rechargeable batteries such as those employing nickel and cadmium, whose recycling or proper disposal was being encouraged.

U.S. exporters were required to provide the Drug Enforcement Administration (DEA) of the U.S. Department of Justice at least 15 days advance notice of shipments to Colombia of certain chemicals, including potassium permanganate, that might be diverted to illicit manufacture of cocaine (61 FR 13759-13760). This requirement became effective March 28 upon DEA's revoking of regular customer status for Colombian customers.

Production

Ore and Concentrate.—The only output consisted of shipments from stocks, no production, of a small amount of manganiferous material for use in coloring brick. This material was mined in Cherokee County, SC, and had a natural manganese content in the range of 5% to 15%. Shipments data were not published to avoid disclosing proprietary data.

Ferroalloys, Metal, and Synthetic Dioxide.—Production statistics for these materials were not published to avoid disclosing proprietary data. Elkem Metals Co. was the only domestic producer of manganese ferroalloys, which was at its Marietta, OH, plant. *(See table 3.)*

Pyron Corp. began production in March of its manganese sulfide plus, a powder metallurgy additive. This product resulted from process development at Pyron, which had manufacturing facilities at Niagara Falls, NY, and Greenback, TN. Pyron, a subsidiary of the Zemex Corp., had been the distributor of manganese sulfide manufactured by Elkem Metals. This business was sold in 1995 to Sweden's Höganäs AB, and production of the sulfide was then transferred to Sweden.

Late in the year, Kerr-McGee Chemical Corp. completed an expansion that brought the annual capacity of its EMD plant at Henderson, NV, to 25,900 tons (Kerr-McGee Corporation, 1997, p. 14).

Consumption, Uses, and Stocks

Data relating to manganese end use plus certain other information indicated that metallurgical applications accounted for most domestic manganese consumption, 85% to 90% of which has been for steelmaking. This is the typical usage pattern for most industrialized countries (Mining Magazine, 1990). Reported data for U.S. ore consumption indicated that unit consumption of manganese in ironmaking, which could not be published to avoid disclosing proprietary data, was roughly 4% below the comparatively low level for 1995. Reported data for U.S. consumption of manganese ferroalloys and metal indicated a decline of a similar extent for manganese unit consumption in steelmaking. These data continued to suggest some shifting from the use of ferromanganese to silicomanganese by steelmakers. *(See tables 4 and 5.)* Relatively small quantities of manganese were used for alloying with nonferrous metals, chiefly in the aluminum industry as manganese-aluminum briquets. Indications were that use of the recently introduced briquet containing 85% manganese was growing as opposed to use of the traditional briquet containing 75% manganese. A review of developments in the metallurgy of the ends of aluminum cans indicated that for the past three decades the ends have been fabricated from the Al-Mg-Mn alloy 5182 (McBride, Sanders, and Reavis, 1996).

Domestic consumption of manganese ore in 1996 was 478,000 tons and yearend stocks were 319,000 tons. Because of the need to avoid disclosing proprietary data, these figures cannot be disaggregated into end-use segment and also do not include relatively small quantities associated with ironmaking.

Comparatively small amounts of manganese were used domestically in animal feed, brick coloring, dry cell batteries, manganese chemicals, and plant fertilizers. These were among the many nonmetallurgical applications of manganese (Weiss, 1977; Harries-Rees, 1993; Major-Sosias, 1996). The source of manganese units for these applications was mainly manganese ore.

Data on domestic consumption of manganese ore, exclusive of that consumed within the steel industry, are collected by means of the "Manganese Ore and Products" survey. By means of this survey, approximately 15 firms were canvassed that process ore by such methods as grinding and roasting or consume it in the manufacture of dry cell batteries and manganese ferroalloys, metal, and chemicals. For this segment of ore consumption, the collective consumption of these firms is believed to constitute that of the United States except for negligible quantities consumed by other firms, if any. In 1996, full-year responses were obtained from all but three plants. The missing data were estimated on the basis of information received in prior years and data trends of other firms having similar business activities. The data reported were thus estimated to represent almost 97% of total consumption.

Further developments involving U.S. suppliers of manganese

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materials for agricultural uses included the acquisition early in the year of the Pittsburg, KS, plant of AlliedSignal Inc. by the Inspec Group PLC of the United Kingdom. Manganese sulfate is produced at this plant. The acquisition was carried out by an Inspec subsidiary, Allco Chemical Corp. of Dallas, TX. Also as discussed in the World Review section of this report, TETRA Technologies Inc., with headquarters near Houston, TX, acquired Mexico's Industrias Sulfamex S.A. de C.V., also a producer of manganese sulfate.

The Ethyl Corp. reported that sales of its manganese-containing octane-enhancing additive, methylcyclopentadienyl manganese tricarbonyl (MMT, "HiTEC 3000"), increased in 1996. Ethyl had started selling MMT to the U.S. refining industry in December 1995. MMT was being manufactured for Ethyl under a long-term supply contract with Albemarle Corp., formerly a wholly owned subsidiary of Ethyl that had been spun off in February 1994 (Ethyl Corporation, 1997). Use of MMT continued to face opposition because of health concerns and objections of U.S. carmakers.

The trend continued in the battery industry for alkaline cells, in which EMD is used, to displace carbon-zinc cells, in which natural manganese dioxide is employed. The share of alkaline cells in the consumer market was reported to have risen to 80% in the United States and to be advancing from 40% to 60% in Japan (Powers and MacArthur, 1997, p. 3).

Among the largest battery companies with headquarters in the United States, Rayovac Corp., Madison, WI, and Duracell International Inc., Bethel, CT, underwent changes in ownership. As of September, an 80% share in Rayovac was acquired by Thomas H. Lee, a Boston-based investment firm, and its affiliates. A merger of Duracell and the Gillette Company was completed late in December. The Eveready Battery Co. adopted Energizer as its new trade name in the latter part of 1996.

A laboratory investigation demonstrated that existing processes used in the mining industry could be applied for recycling the components, particularly mercury, of high-mercury batteries. The study was conducted on batteries that were based on manganese and other metals and have military applications (Bowers and Beyke, 1996).

Prices

For 1996, with the price of manganese in metallurgical-grade ore taken as 1.0, the corresponding prices per manganese unit were approximately 2.6 for high-carbon ferromanganese, 2.3 for silicomanganese, 4.6 for medium-carbon ferromanganese, and 9.9 for manganese metal. These price factors are based on year-average prices such as discussed in the following.

Manganese Ore.—The midrange value for the average price, c.i.f. U.S. ports, of metallurgical-grade ore containing 48% manganese was assessed as $2.55 per metric ton unit (mtu). It is recognized that prices somewhat above or below this value applied, depending on ore quality, time of year, and nature of the transaction. The price of a metric ton of ore is obtained by multiplying the mtu price by the percentage manganese content of the ore. The ore market consists of a number of submarkets because of differences between ores according to such various end uses as ferroalloy production, blast furnace ironmaking, and battery manufacture.

Because the metric ton unit is 1% of a metric ton, i.e., 10 kilograms of contained manganese, the price of manganese in ore in 1996 and 1995 can be expressed as 25.5 and 24.0 cents per kilogram, respectively. These values indicate an increase of more than 6% in U.S. c.i.f. price or somewhat less than the increases in f.o.b. price in international markets.

The main price evolution in international markets for metallurgical-grade ore occurred shortly before the April 1 start of the Japanese 1996 fiscal year. Japanese consumers reached agreement at that time on f.o.b. prices per mtu for delivery during the annual contract year that were $2.19 for Australia's Broken Hill Pty. Co. Ltd. (BHP) and $2.09 for South Africa's Samancor Ltd., for price increases of 7.4% and 7.2%, respectively. At about the same time, Japanese customers agreed to an f.o.b. price of $2.14 per mtu for ore from Western Australia's Portman Mining Ltd., which constituted an increase of 9.7%.

Manganese Ferroalloys.—For the principal ferroalloys, the generally rising trend in prices that developed in 1995 was reversed in 1996. As a result, prices at yearend 1996 were at about the same level as at the start of 1995. The price information that follows refers to quotations for U.S. imports, as public information on current prices for domestic products were not available. English units also were the basis for price quotes in the United States as given in sources such as Platt's Metals Week.

Price trends were similar in 1996 for high-carbon and medium-carbon ferromanganese. For both grades, the middle of the price range was about 14% less at the end of the year than at the beginning. Generally also for both grades, the price drifted downward from January into June and then began to drop more rapidly at almost a steady rate. The price range for high-carbon ferromanganese containing 78% manganese, per long ton of alloy f.o.b. Pittsburgh or Chicago warehouse, began and ended the year at $560 to $575 and $480 to $500, respectively. The middle of the price range averaged $532 for the year, a further small increase of 2.5% above that of the preceding year. The price range for medium-carbon ferromanganese with a manganese content of 80% to 85% and a nominal carbon content of 1.5%, in cents per pound of manganese f.o.b. warehouse, was 54.5 to 56 and 46.5 to 48 at the beginning and end of the year, respectively. The middle of the price range averaged 52.8 for the year, which was 6.2% above that for 1995.

According to trade journal reports, the downward pressure on ferromanganese prices came at first from the availability of manganese units at lower prices in the form of silicomanganese and steel scrap and later on because of an oversupply situation coupled with a seasonal decline in steel production.

For silicomanganese, the middle of the price range fell 37% between the beginning and end of the year and averaged somewhat more than 10% less than in 1995. The price of silicomanganese fell more or less progressively through May at

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a relatively rapid rate and thereafter relatively slowly. The price range for imported silicomanganese with 2% carbon, in cents per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, was 36.75 to 39.5 and 23.75 to 24.25 at the beginning and end of the year, respectively. The middle of the price range averaged 28.3 for the year. Trade journals cited oversupply from areas such as China and Eastern Europe as factors behind the decline in silicomanganese price.

Manganese Metal.—For the producer price for bulk shipments of domestic material, per pound f.o.b. shipping point, Platt's Metals Week listed $1.15 throughout the year. This was the same figure as given effective in October 1995, and implied a year-average price 4.6% greater than in 1995. American Metal Market, which had listed a range of $1.14 to $1.15 as of October 1995, indicated that the price was in-creased to $1.15 to $1.17 as of mid-February, or somewhat more than 1%. North American transaction prices as given by Ryan's Notes were roughly 12% less than producer price.

Foreign Trade

In terms of manganese units contained, the volume of trade in the principal manganese materials was the greatest of the 1990's so far. Principally because of a doubling of ore exports, the quantity of manganese exported increased about one-sixth to the greatest overall total since 1991. *(See table 6.)* The quantity of manganese imported increased about one-fifth, again to the greatest overall total since 1989 and with nearly all categories showing increases in volume. *(See table 7.)* Also on the basis of content, the ratio, ferroalloy plus metal imported divided by ore plus dioxide imported, decreased for the third consecutive year, to 2.1:1. This was again the lowest such ratio since 1989.

Among exports, unit values again indicated that about four-fifths of the ore was unprocessed material of metallurgical grade. About two-thirds of the ore with higher unit value went to Canada. Exports of ferromanganese containing more than 2% carbon, which were about one-third of total ferromanganese exports, were virtually unchanged, but those of other ferromanganese decreased about one-sixth. The modestly increased exports of metal again were the greatest since 1990. Reexports of ore, ferromanganese, silicomanganese, and metal were, in tons, 504; 3,776; 4,057; and 209, respectively; all went to Canada except for small amounts of ore and metal. Reexports of ore all had relatively high unit value.

Among imports, average manganese contents of 48.3% for ore and 78.4% for ferromanganese were at about the middle of the ranges for the past decade. For ore, Gabon was again the dominant source, about 60% of the total, of a one-fifth greater volume of imports. For ferromanganese, an increase also of about one-fifth in manganese imported was caused especially by a rise in imports of medium-carbon ferromanganese (particularly those from China and Japan) that reached a level surpassed only in 1988.

For silicomanganese, an increase of about 6% was enough to produce a record high import volume. Receipts from Australia, India, Kazakstan, and Venezuela were the most since at least 1970. Reported imports of spiegeleisen increased 74% to 455 tons, all from South Africa at relatively high unit value.

Among imports of manganese chemicals, receipts of a record quantity from Australia helped produce for manganese dioxide a volume again second only to that in 1994. Imports of dioxide appeared again to have been wholly synthetic material. Data for imports under the classification "Other sulfates" suggested that imports of manganese sulfate could have increased by about 40%, which was approximately the increase in volume for material in that class each from China and Mexico. Receipts from China were 5,875 tons at a value of $2.0 million and from Mexico 19,489 tons at a value of $9.2 million.

The Generalized System of Preferences (GSP) program was reauthorized effective October 1, 1996, through May 31, 1997, retroactive to August 1, 1995 (Platt's Metals Week, 1996). For the time period specified, preferential tariff treatment was restored, with certain exclusions, for U.S. imports from developing countries of manganese dioxide; permanganates; manganese sulfate; low- and medium-carbon ferromanganese; silicomanganese; and manganese metal, other.

World Review[1]

The prominent position attained by China in the world's manganese industry is indicated in the data for world production of ore and ferroalloys at the end of this report. *(See tables 8 and 9.)*

Australia.—Monthly production reports of BHP indicated that manganese ore production at BHP's Groote Eylandt Mining Co. Pty. Ltd. (GEMCO) subsidiary totaled 1,810,000 tons, or only 11,000 tons less than the corresponding total for 1995. In September, GEMCO marked the 30th anniversary of the beginning of shipments to customers in Japan, noting that it has maintained relations with certain of them ever since. BHP initiated a trial of toll processing of GEMCO ore into high-carbon ferromanganese at the Tokushima plant of Japan's Nippon Denko Co. Ltd., to be carried out during the Japanese fiscal year ending March 1997.

A recent investigation of samples from the Groote Eylandt deposit found that weathering has played a greater role in the evolution of the deposit than had been thought. Intense leaching and reprecipitation were believed to have led to complete replacement of the original sedimentary and diagenetic manganese minerals (Dammer, Chavis, and McDougall, 1996).

The Pilbara Manganese Project of Portman was sold to Valiant Manganese Pty. Ltd., a subsidiary of Valiant Consolidated Ltd. Besides Portman, Valiant was the other operator of a manganese mine in the Woodie Woodie area of Western Australia. The midyear sale included all of Portman's

[1]Discussions by country of the more significant developments during 1996 were based in a number of instances on news items in trade journals such as American Metal Market, Metal Bulletin (London), Platt's Metals Week, Ryan's Notes, and The TEX Report (Tokyo). These items have not been acknowledged individually because the information they conveyed often was aggregated, possibly with that from other sources.

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manganese interests except stockpiled lump manganese ore, ownership of which did not pass to Valiant until the end of October.

Brazil.—Production of manganese ore by Cia. Vale do Rio Doce (CVRD) increased at both its Azul Mine in the Carajás region and its Urucum Mineraçao S.A. subsidiary in Mato Grosso do Sul State. Output in thousand tons and percentage change from 1995 (in parenthesis) were 1,421 (+12%), the second successive new record; and 260 (+26%); respectively. Of ore sales that totaled 1,179 thousand tons, 54% was to foreign markets (Cia. Vale do Rio Doce, 1997).

Manganese ore shipments by Indústria e Comércia de Minérios S.A. (ICOMI) from operations at Serra do Navio, Amapá Territory, totaled 366,000 tons. Destinations of the shipments, which were through Porto de Santana on the Amazon River, were, in tons, 167,000 to Europe, 115,000 to South America (including Brazil), 64,200 to Asia, and 18,800 to North America (Skillings Mining Review, 1997b). Shipments overall were about 7% less than in 1995, with decreased shipments to Europe moderated by increased shipments to Asia.

The history and geology of the Morro da Mina Mine near Conselheiro Lafaiete in Minas Gerais State, southeastern Brazil, and the production practices followed there were detailed (Strong, 1996). This mine was noted to be a relatively small but long-lived producer of manganese ore, having yielded 8.6 million tons of oxide ore and 3.4 million tons of manganese silicate-carbonate protore during 1902-95. The then U.S. Steel Corp. purchased the mine in 1920 and sold it in 1978.

Early in the year, Brazil's production of manganese ferroalloys was bolstered by the return to full capacity of operations at the plant of Eletrosiderúrgica Brasileira S.A. (Sibra). The Sibra plant, near Salvador in Bahia State, was being managed by Vale-Usiminas Participações, the equally owned company that CVRD and Usinas Siderúrgica de Minas Gerais S.A. formed in 1995. Brazil lost a relatively small amount of manganese ferroalloy production capacity, mostly ferromanganese, when the Caemi Group closed the plant of its subsidiary, Cia. Ferroligas do Amapá in the first part of the year. This plant, in operation only since 1990, was in the Porto de Santana area in northeastern Brazil and had an annual capacity for high-carbon ferromanganese of 23,000 tons. It was being fed with manganese ore from the affiliated operations of ICOMI's mine.

China.—Imports of manganese ore were reported to have advanced nearly one-fourth to a record 1,585,000 tons. In decreasing order of magnitude, the leading ore source countries were again Australia, Myanmar, Gabon, and South Africa, which together accounted for 93% of total imports (The TEX Report, 1997). The quality of ore being imported into China was generally superior to that of domestic sources. An example of the latter is the Chadian phosphorus-manganese deposit in Shaanxi Province, central China, in which the manganese content of the ores was in the range of 11% to 24% and whose geology and conditions of formation were investigated (Liu, Fan, and Ye, 1996).

China's substantial ferroalloy industry, which in 1995 had exported more than 600,000 tons of manganese ferroalloys, appeared to be giving greater emphasis to environmental concerns.

In the electrolytic industry, an export-oriented joint venture, JMC-Xinshao Co. Ltd., was formed between Chinese and Japanese interests for production of EMD at Shaoyang City, Hunan Province. The Chinese participants, the Hujiang State Exclusive Raw Materials Factory (703 Factory) and the Hunan Provincial Import & Export Corp., made up about two-thirds of the venture, mostly in terms of facilities. On the Japanese side, the major participant was Japan Metals & Chemicals Co. Ltd. (JMC), a producer of EMD in Japan, and the minor participant was Sumitomo Corp. The joint venture was formed in the first part of the year and was shipping samples by the end of the summer. Its annual capacity of 10,000 tons resulted from a combination of existing and new facilities.

China's exports of manganese metal were virtually the same in 1995 as in 1994, 50,000 tons. The majority of shipments continued to be to Japan and the Netherlands.

Gabon.—Exports of manganese ore produced from the Moanda Mine of Compagnie Minière de l'Ogooué S.A. (COMILOG) totaled 1,977,000 tons, of which 1,929,000 tons was metallurgical-grade ore and 48,100 tons was battery-grade ore. Shipments were made in 62 cargoes via the Port of Owendo (Skillings Mining Review, 1997a). Compared with the corresponding figures for 1995, exports were about 2% greater overall, about 4% greater for metallurgical-grade ore, and only about one-half as much for battery-grade ore.

In June, ERAMET, a French producer of nickel and high-speed steel, proceeded with its plan for increasing its shareholding in COMILOG from 17% to 46%. ERAMET thus became the largest shareholder in COMILOG and took over its management. Subsequently, ERAMET and COMILOG began a restudy of the feasibility of establishing a ferromanganese plant in Gabon, a possibility whose consideration dates back more than 20 years. The new study was of a plant near the Moanda Mine with annual capacity of 100,000 tons.

Georgia.—Privatization of Georgia's manganese industry moved ahead for the Zestafoni ferroalloys plant but not for the Chiatura Mine. The Government contracted with North Atlantic Resources Inc. of New York, NY, a consultancy, and the Russian-Georgian Bank of Reconstruction and Development of Tbilisi to manage the Zestafoni plant for a 10-year period. Shareholders selected a new board of directors for the plant in March, and the plant's furnaces were restarted in April.

Iran.—In the first half of the year, Navid Manganese commissioned a high-carbon ferromanganese plant near Esfahan in central western Iran. The plant's annual capacity of 30,000 tons was 10 times that of a nearby predecessor pilot plant, which was to be shut down later on. Ore for these operations initially was sourced from a mine near Qom to the north and west of Esfahan. Because the manganese content of this ore was only about 30%, consideration was being given to replacing it with higher-grade imported ore.

Japan.—Overall imports of metallurgical-grade manganese

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ore decreased less than 1% to 1,169,000 tons. For ore containing more than 39% manganese, imports declined somewhat more than 5% to 889,000 tons, 84% of which was from Australia plus South Africa. Imports from South Africa fell by almost 30%. For ore containing no more than 39% manganese, imports rose by nearly 20% to 279,000 tons, virtually all of which was from India and South Africa. Imports of ferruginous manganese ore decreased about 4%, from 86,000 to 82,000 tons, virtually all of which was from Ghana (58%) and India (41%).

Within a production of manganese ferroalloys that only slightly exceeded that in 1995, production of refined ferromanganese and silicomanganese increased by roughly one-sixth. The Tokushima plant of Nippon Denko in Tokushima Prefecture, southwestern Japan, was being expanded into fully integrated production of manganese ferroalloys. Facilities were being installed so that low- and medium-carbon ferromanganese could be produced in addition to the existing production of high-carbon ferromanganese and silicomanganese. This plant also was involved in an international alliance whereby Australian manganese ore was being toll processed into high-carbon ferromanganese. As discussed under South Africa, Japanese companies participated in two joint ventures set up for production of refined manganese ferroalloys in South Africa.

Imports of manganese ferroalloys decreased, by about 6% overall to 344,000 tons, 10% for ferromanganese to 111,000 tons, and 3% for silicomanganese to 233,000 tons. Most imports of ferromanganese were high-carbon ferromanganese, of which South Africa (48%) and China (42%) were the main sources. For silicomanganese, the main sources were Ukraine (30%) and China (23%), receipts from Ukraine having increased by about one-fifth while those from China fell by about one-third.

Exports of manganese ferroalloys decreased 17% overall to 37,500 tons. Most of the total was accounted for by ferromanganese containing less than 2% carbon, 33,700 tons, of which exports to the United States, 21,600 tons, were about one-sixth greater than in 1995.

For EMD, production declined about 3% to 58,500 tons while exports were down roughly 9% to 32,000 tons. As discussed under China, Japanese firms entered into a joint venture for production of EMD in China.

Imports of unwrought manganese metal, including scrap, increased again (about 9%) to 36,800 tons, practically all of which was from China (60%), South Africa (36%), and the United States (3%), or nearly the same pattern for sources as in 1995.

Kazakstan.—The production program at the Ermak ferroalloy plant at Aqsu in northeastern Kazakstan was being structured so as to achieve for manganese ferroalloys, principally silicomanganese, an annual output in the range of 100,000 tons. Most of this output was to come from one of the plant's four melting shops. The Ermak plant, along with the Aktyubinsk ferroalloy plant and the Donskoy chromium mine, was part of the Kazchrome Transnational Corp. that had been established by Japan Chrome Corp. and later joined by the Trans-World Group.

Mexico.—Output levels for the ore products of Cía. Minera Autlán (Autlán) were relatively comparable to those in 1995. Data for salable production in 1996, in tons, were manganese carbonates plus ore from the Terrenates Mine, 103,000; oxide nodules, 363,000; and manganese dioxide plus manganous oxide, 19,000. Most of this production was from operations in the Molango District of Hidalgo State, where nodule production increased more than 3%. Supplemental quantities were produced from the Terrenates Mine in Chihuahua State. Autlán's salable production of manganese ferroalloys rose across the board, by 33% for high-carbon ferromanganese, 8% for medium-carbon ferromanganese, and 37% for silicomanganese.

In July, Sulfamex was acquired by TETRA Technologies. Sulfamex has a plant near Tampico, Veracruz State, for production of manganese sulfate and related products that are sold mostly to U.S. customers. Sulfamex' plant was capable of annually producing upwards of 20,000 tons of sulfate, on the basis of monohydrate.

Saudi Arabia.—Late in the year, the four 27-megavolt-ampere furnaces at the new plant of Gulf Ferro Alloys Co. (SABAYEK) were brought into operation, initially for production of silicomanganese, ferrosilicon, and silicon metal. As reported at the 1995 INFACON, one furnace at this plant was to be capable of producing either silicomanganese or ferromanganese and another either silicomanganese or ferrosilicon, for an overall annual capacity for silicomanganese of 30,000 tons (Al Mokrin, 1995). SABAYEK's plant is located in the Jubail Industrial City, which is near Saffaniyah on the Persian Gulf, south of Kuwait.

South Africa.—According to preliminary data, metallurgical-grade ore still accounted for more than 98% of manganese ore production, the balance being chemical-grade ore. Total ore production and production of metallurgical-grade ore were marginally greater than in 1995, while production of chemical-grade ore rose by more than one-fifth. Among categories comprising the production subtotal for metallurgical-grade ore, ore containing 30% to 40% manganese again accounted for 36% of the subtotal, while the portion of the subtotal accounted for by ore containing more than 48% manganese increased from 54% to 58%. Production of ore in this highest grade category advanced by 8%. Sales of manganese ore by The Associated Manganese Mines of South Africa Ltd. (Assmang) for the fiscal year ending June 30, 1996, were 1,320,000 tons, an increase of 11% over that for the prior fiscal year.

Wellbeloved and Glück (1996) reviewed the South African manganese ore industry and the extraction of manganese from South African ores via the production of manganese sulfate solutions. Geologists reported on the evolution of the mineralogy of the Kalahari manganese field (Gutzmer and Beukes, 1996b), continued to debate the origin of its extensive deposits (Beukes and Gutzmer, 1996; Cornell and Schütte, 1996), and described the deposits of the Postmasburg manganese field (Gutzmer and Beukes, 1996a).

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Two joint ventures were established for the production of refined manganese ferroalloys. Each consisted of a major integrated South African manganese producer, a Japanese ferroalloy producer, and a Japanese trading company. ADVALLOY, formed at midyear, was composed of Samancor (50%), JMC (35%), and Mitsui & Co. Ltd. (15%). This joint venture projected annual production of about 75,000 tons of mostly medium- and low-carbon ferromanganese plus also ultra-low-carbon grades of ferromanganese and silicomanganese. Using high-carbon ferromanganese and silicomanganese supplied by Samancor, trial production was to begin late in 1997 and commercial production in 1998. To accomplish this, a 30-ton converter and two relatively small electric furnaces were to be installed at Samancor's manganese ferroalloy plant at Meyerton. In connection with this, Samancor acquired the Midland plant of Polifin Ltd., with the plan to convert this calcium carbide facility to production of as much as 120,000 tons annually of silicomanganese as a replacement for that being used in the ADVALLOY joint venture.

The second joint venture, established a few months later, was composed of Assmang's Feralloys Ltd. subsidiary (50%), Mizushima Ferro Alloy Co. Ltd. (40%), and Sumitomo (10%). Subsequently named Cato Ridge Alloys (Pty) Ltd., this joint venture was aimed at production of about 30,000 tons annually of low- and medium-carbon ferromanganese. Facilities being established at Feralloys were to begin operation early in 1998 using ore feed from Assmang.

Samancor started up its metal-from-slag plant in February. This plant began recovering metal for remelting from slag that has accumulated at the Meyerton plant from decades of manganese ferroalloy smelting. Byproduct barren slag for use as aggregate by the construction industry was being returned to a contractor operating in conjunction with Samancor.

A jigging process was replacing hand sorting for recovery of salable metal from low-grade alloy at the Witbank plant, Gauteng Province, of the Transalloys Division of Highveld Steel and Vanadium Corp. Ltd. This process, a joint venture between Mintek and Titaco Consolidated Investments, was being carried out intermittently on a toll treatment basis (Mintek Bulletin, 1996).

Spain.—Pechiney's sale of its 72% interest in Hidro-Nitro Española SA (HNE) to Ferroatlantica SL was completed in April. Ferroatlantica thus became Spain's only producer of manganese ferroalloys, and France's Pechiney completed its withdrawal from that industry. A producer of specialty manganese ferroalloys, HNE's typical annual output was 20,000 tons of silicomanganese, 5,000 tons of low-carbon ferromanganese, and 5,000 tons of ferromanganese powder for welding applications.

Ukraine.—In an assessment of the outlook for Ukraine's mining and metallurgical industries, the Minister of Industry projected that manganese ore output would remain less than one-half that just prior to the dissolution of the U.S.S.R. and decrease further within 15 years. He gave for manganese ore production (million tons) 6.9 in 1990, 3.2 in 1995, 3.3 in 2000, and 2.7 in 2010 (Mazur, 1996).

The 30th anniversary of the Nikopol' ferroalloy plant was commemorated in an issue of the Russian-language journal Stal' (Koval', 1996). Also described in this issue was technology developed at this plant for electrosilicothermic production of medium-carbon ferromanganese using manganiferous low-phosphorus slags and silicomanganese screenings (Gasik and others, 1996).

Current Research and Technology

The geochemistry of manganese was the subject of a book on the world's supergene deposits (Varentsov, 1996) and of a paper on the mechanism of sedimentation of carbonates in black shales (Calvert and Pedersen, 1996). The status of technology for mining marine nodules and crusts was reviewed (Chung, 1996).

Studies were conducted in Ghana on sulfuric acid leaching of Nsuta ore with the aim of increasing utilization of rejects from processing carbonate ore (Momade, 1996).

The kinetics of reactions involved in smelting manganese ore into ferromanganese was investigated for samples of ore from Australia and South Africa (Berg and Olsen, 1997). In India, a study was made of the possibility of using a calcium silicide treatment to reduce the phosphorus content of ferromanganese (Sen, Basu, and Gupta, 1996).

A phase diagram of the manganese-oxygen system was obtained using data from solution calorimetry employing molten lead borate as the solvent (Fritsch and Navrotsky, 1996).

Several approaches for preparing manganese-containing electrodes for use in lithium batteries were reported (Gao and Dahn, 1996; Liu, Farrington, Chaput, and Dunn, 1996; Manthiram, Dananjay, and Tsang, 1996). Development and performance were described for titanium anodes surfaced with a titanium-manganese alloy containing 16% manganese that were used to manufacture EMD at the Rustavi plant in Georgia (Trusov and Kryuchkova, 1996).

Progress in achieving a commercial process for electrodepositing zinc-manganese coatings on steel and their ability to provide enhanced corrosion resistance were reviewed (Wilcox and Petersen, 1996).

Also reviewed was the status of knowledge about the role of manganese in the photosynthetic oxidation of water to oxygen, a reaction critical to animal and plant life (Yachandra, Sauer, and Klein, 1996).

The potential for airborne manganese to produce neurological effects years after a relatively high-level exposure was explored in a study of former Chilean manganese miners, in whom it was possible to detect impaired motor performance (Hochberg and others, 1996). The possibility that adverse health effects would arise from low-level exposure to manganese from the use of MMT in gasoline was assessed. One study found it unlikely that Canadian usage represented a significant health risk (Egyed and Wood, 1996). The Environmental Protection Agency reviewed the issues associated with the U.S. situation, noting uncertainties resulting from lack of information (Davis and Elias, 1996).

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Outlook

The trend of manganese demand, domestically and globally, will continue to follow closely that of steel production. Although some nonmetallurgical components of manganese demand may experience higher growth rates than for steel production, especially batteries, this will have only a minor effect on overall manganese demand.

For the past decade, U.S. apparent consumption of manganese has been within roughly plus or minus 10% of about 660,000 tons of contained manganese. This largely has been a consequence of a reasonably comparable degree of variation in domestic steel production during the same period. Manganese demand, which is presented as apparent consumption in table 1, generally has shown an increasing trend as has the level of activity in the steel industry. It may be that manganese apparent consumption has not traced steel production precisely because of the influence of unmeasured changes in stocks of manganese materials, such as those of importers. The effect of this may have outweighed changes in demand by steelmakers.

Forecasts of the International Iron and Steel Institute (IISI) and others that were publicized in 1996 suggest that domestic steel output, the main determinant of manganese demand, is likely to be relatively steady throughout the remainder of the 1990's. Accordingly, the midterm outlook for U.S. apparent consumption of manganese is to remain near 660,000 tons of contained manganese. This outlook for a stable manganese demand assumes no significant change in manganese unit consumption by U.S. steelmakers. The majority of U.S. demand for manganese units will be met by imports.

For the world, forecasts by IISI and others for world steel demand during the balance of the 1990's suggest an annual growth rate in the vicinity of 2%. Demand is foreseen to be relatively static in traditional industrialized countries and expected to grow the most in China, other Asian countries besides Japan, and Latin America. For the midterm, the global growth rate in demand for manganese seems likely to be somewhat less than that for steel because of an anticipated decline in manganese unit consumption in the steel industries of countries that are industrializing or restructuring.

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[2]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT MANGANESE STATISTICS 1/

(Thousand metric tons, gross weight)

	1992	1993	1994	1995	1996
United States:					
Manganese ore (35% or more Mn):					
Exports	13	16	15	15	32
Imports for consumption	247	232	331	394	478
Consumption	438	389	449	486	478 2/
Stocks, Dec. 31: Consumers	276	302	269	309	319 2/
Ferromanganese:					
Exports	13	18	11	11	10
Imports for consumption	304	347	336	310	374
Consumption	339	341	347	348	326
Stocks, Dec. 31: Consumers and producers	28	30	36	33	27
Consumption, apparent, manganese 3/	596	696	694	676	NA
Ore price, dollars per metric ton unit, c.i.f. U.S. ports	3.25	2.60	2.40	2.40	2.55
World production of manganese ore	21,800 r/	20,800 r/	18,000 r/	23,000 r/	22,300 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits, except prices.

2/ Exclusive of iron and steel plants.

3/ Thousand metric tons, manganese content. Based on estimates of average content for all significant components excepts imports, for which content is reported.

TABLE 2
U.S. GOVERNMENT DISPOSAL AUTHORITIES AND YEAREND INVENTORIES FOR MANGANESE MATERIALS IN 1996 1/

(Metric tons, gross weight)

		Physical inventory, Dec. 31				
		Uncommitted			Sold,	
Material	Disposal authority	Stockpile grade	Nonstockpile grade	Total	pending shipment	Grand total
Natural battery ore	127,000	110,000	16,800	127,000	5,040	132,000
Synthetic manganese dioxide	2,730	2,730	--	2,730	--	2,730
Chemical ore	149,000	149,000	81	149,000	--	149,000
Metallurgical ore	1,040,000	741,000	392,000	1,130,000	165,000	1,300,000
High-carbon ferromanganese	727,000	968,000	--	968,000	--	968,000
Medium-carbon ferromanganese	--	17,700	--	17,700	--	17,700
Silicomanganese	--	183	--	183	--	183
Electrolytic metal	9,050	9,050	--	9,050	690	9,740

1/ Data rounded to three significant digits; may not add to totals shown.

TABLE 3
DOMESTIC PRODUCERS OF MANGANESE PRODUCTS IN 1996

		Products 1/				
Company	Plant location	FeMn	SiMn	Mn	MnO2	Type of process
Chemetals Inc.	Baltimore, MD	--	--	--	X	Chemical.
Do.	New Johnsonville, TN	--	--	--	X	Electrolytic.
Elkem Metals Co.	Marietta, OH	X	X	X	--	Electric furnace and electrolytic.
Kerr-McGee Chemical Corp.	Hamilton, MS	--	--	X	--	Electrolytic.
Do.	Henderson, NV	--	--	--	X	Do.
Ralston Purina Co.:						
Eveready Battery Co.	Marietta, OH	--	--	--	X	Do.

1/ FeMn, ferromanganese; SiMn, silicomanganese; Mn, manganese metal; MnO2, synthetic manganese dioxide.

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TABLE 4
U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 1996 1/

(Metric tons, gross weight)

End use	Ferromanganese			Silico-manganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	189,000	68,000	257,000	93,500	1,900
Stainless and heat-resisting	13,100	(2/)	13,100	6,020	1,500
Full alloy	18,900	5,100	24,000	29,300	(2/)
High-strength, low-alloy	16,300	4,090	20,400	7,340	(2/)
Unspecified 3/	330	248	578	371	721
Total steel	238,000	77,400	315,000	137,000	4,110
Cast irons	8,530	488	9,020	797	--
Superalloys	W	W	W	--	125
Alloys (excluding alloy steels and superalloys)	761	383	1,140	(4/)	17,800 5/
Miscellaneous and unspecified	--	W	W	(4/)	W
Total consumption	247,000	78,300	326,000	137,000 6/	22,000
Total manganese content 7/	193,000	62,700	256,000	90,600	22,000
Stocks, Dec. 31:					
Consumers and producers	12,800	14,600	27,300	7,760	4,010

W Withheld to avoid disclosing company proprietary data; included with "Alloys (excluding alloy steels and superalloys)."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
3/ Includes electrical and tool steel, and items indicated by (2/).
4/ Withheld to avoid disclosing company proprietary data.
5/ Approximately 85% of this combined total was for consumption in aluminum alloys.
6/ Internal evaluation indicates that silicomanganese consumption is considerably understated.
7/ Estimated based on typical percent manganese content.

TABLE 5
U.S. UNIT CONSUMPTION OF MANGANESE IN STEELMAKING 1/

(Kilograms per metric ton of raw steel unless otherwise specified)

Form used		1995	1996
Basis: Production of raw steel 2/ and steel castings	million tons	96.2 r/	96.6
Ore 3/		--	--
Ferromanganese		2.75 r/	2.56
Silicomanganese		0.89	0.93
Manganese metal		0.05	0.04
Total		3.69 r/	3.54

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ As ingots, continuous- or pressure-cast blooms, billets, slabs, etc.
3/ Containing 35% or more manganese.

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TABLE 6
U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY 1/

Country	1995 Gross weight (metric tons)	1995 F.a.s. value (thousands)	1996 Gross weight (metric tons)	1996 F.a.s. value (thousands)
Ore and concentrates with 20% or more manganese:				
Belgium	1,410	$113	3,410	$272
Brazil	3,080	246	2,290	216
Canada	6,980	1,040	5,800	1,140
China	--	--	5,620	450
France	--	--	2,710	216
Japan	1,320	105	2,860	229
Sweden	234	19	3,380	270
Other	2,360 2/	224 2/	5,550	1,210
Total	15,400	1,750	31,600	4,000
Ferromanganese, all grades:				
Canada	8,950	8,110	8,700	7,750
Japan	514	523	--	--
Mexico	477	525	751	763
Other	1,080 2/	963 2/	341	334
Total	11,000	10,100	9,800	8,850
Silicomanganese:				
Canada	6,000	4,700	4,810	4,000
Luxembourg	1,200	496	--	--
Mexico	609	415	306	277
Other	34	41	153	116
Total	7,840	5,650	5,270	4,390
Metal, including alloys and waste and scrap:				
Belgium	55	139	544	1,240
Canada	1,600	3,930	1,030	2,780
Japan	893	2,170	1,020	2,520
Netherlands	928	1,920	470	1,820
United Kingdom	946	1,200	1,100	1,570
Other	1,220 2/	3,230 2/	1,680	4,520
Total	5,640	12,600	5,840	14,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Revised; unspecified group of countries differs from that in the 1995 Annual Report.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY 1/

Country	1995 Gross weight (metric tons)	1995 Manganese content (metric tons)	1995 Customs value (thousands)	1996 Gross weight (metric tons)	1996 Manganese content (metric tons)	1996 Customs value (thousands)
Ore and concentrates with 20% or more manganese:						
All grades:						
Australia	60,200	31,600	$5,480	96,000	48,900	$8,840
Brazil	22,900	7,080	514	18,700	5,640	294
China	18,000	7,420	1,150	--	--	--
Gabon	204,000	104,000	20,500	277,000	140,000	27,300
Mexico	62,200	23,600	3,460	43,000	16,100	2,580
Morocco	71	37 2/	15	18	9	5
South Africa	26,000	13,100	2,200	43,500	20,800	3,430
Total	394,000	187,000	33,300	478,000	231,000	42,400
More than 20%, but less than 47% manganese:						
Brazil	21,100	6,130	337	18,700	5,640	294
China	9,500	3,150	617	--	--	--
Mexico	61,800	23,500	3,430	43,000	16,000	2,580
Total	92,400	32,700	4,380	61,700	21,700	2,870
47% or more manganese:						
Australia	60,200	31,600	5,480	96,000	48,900	8,840
Brazil	1,840	957	178	--	--	--
China	8,520	4,270	528	--	--	--
Gabon	204,000	104,000	20,500	277,000	140,000	27,300
Mexico	400	188	30	20	14	7
Morocco	71	37 2/	15	18	9	5
South Africa	26,000	13,100	2,200	43,500	20,800	3,430
Total	301,000	154,000	28,900	416,000	209,000	39,600
Ferromanganese:						
All grades:						
Australia	32,300	24,300	11,400	33,900	25,500	13,500
Brazil	18,300	14,000	8,140	36,400	27,700	17,100
China	--	--	--	11,700	9,440	9,310
France	89,600	69,400	38,800	97,600	76,800	46,600
Italy	5,400	4,840	8,450	5,630	5,050	9,110
Japan	11,500	9,330	8,220	27,100	21,900	22,400
Mexico	22,300	17,700	15,400	24,400	19,600	19,700
Norway	413	338	354	4,910	4,070	4,500
South Africa	129,000	101,000	58,100	132,000	103,000	63,800
Other	1,290 3/	1,080 3/	967 3/	4	4	3
Total	310,000	242,000	150,000	374,000	293,000	206,000
1% or less carbon:						
Italy	5,400	4,840	8,450	5,630	5,050	9,110
Japan	1,540	1,290	1,310	2,480	2,070	2,880
Norway	413	338	354	1,160	961	1,330
South Africa	1,900	1,730	3,250	2,240	2,060	3,910
Ukraine	1,240	1,050	937	--	--	--
Other	28	25	35	24	21	42
Total	10 500	9 270	14,300	11 500	10,200	17,300
More than 1% to 2% or less carbon:						
Brazil	1,650	1,320	1,320	5,210	4,170	4,340
China	--	--	--	11,700	9,440	9,310
France	2,750	2,240	2,150	4,200	3,430	3,290
Japan	10,000	8,040	6,910	24,600	19,800	19,500
Mexico	21,100	16,900	15,100	24,400	19,600	19,700
Norway	--	--	--	3,740	3,060	3,110
South Africa	7,940	6,340	6,350	4,230	3,390	3,710
Other	21	14	8	--	--	--
Total	43,400	34,900	31,800	78,100	62,900	62,900

See footnotes at end of table.

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TABLE 7--Continued
U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY 1/

Country	1995 Gross weight (metric tons)	1995 Manganese content (metric tons)	1995 Customs value (thousands)	1996 Gross weight (metric tons)	1996 Manganese content (metric tons)	1996 Customs value (thousands)
Ferromanganese:						
More than 2%, but not more than 4% carbon:						
Mexico	1,200	762	$310	--	--	--
More than 4% carbon:						
Australia	32,300	24,300	11,400	33,900	25,500	$13,500
Brazil	16,600	12,700	6,790	31,200	23,600	12,700
France	86,800	67,200	36,700	93,400	73,400	43,300
South Africa	119,000	93,400	48,600	125,000	97,200	56,100
Other	18	14	16	62	49	70
Total	255,000	198,000	103,000	284,000	220,000	126,000
Silicomanganese:						
Argentina	9,510	6,180	4,550	7,490	4,870	4,910
Australia	46,300	30,800	23,600	50,300	33,700	29,200
France	21,500	13,600	11,100	20,900	13,800	11,100
Georgia	19,600	13,200	8,320	1,260	884	701
India	39,400	25,800	19,700	47,400	31,200	27,000
Kazakstan	1,000	662	643	10,200	6,370	4,820
Macedonia	--	--	--	11,000	7,460	4,910
Mexico	22,400	14,400	10,800	23,600	15,400	13,300
Norway	9,710	6,010	7,430	10,500	6,440	10,200
Romania	14,700	9,720	9,290	13,600	9,070	7,390
South Africa	99,700	66,300	52,900	93,900	63,300	54,600
Venezuela	18,000	11,900	9,880	24,500	15,600	13,800
Other	3,070 3/	1,910 3/	2,420 3/	8,350	5,000	5,860
Total	305,000	201,000	161,000	323,000	213,000	188,000
Metal:						
Unwrought:						
China	1,100 r/	XX	1,610 r/	1,100	XX	1,800
South Africa	9,120	XX	14,300	8,480	XX	14,000
Ukraine	--	XX	--	524	XX	856
Other	121 r/	XX	132 r/	23	XX	62
Total	10,300	XX	16,100	10,100	XX	16,800
Other:						
France	101	XX	953	102	XX	964
Germany	8	XX	41	169	XX	452
South Africa	--	XX	--	335	XX	585
United Kingdom	268	XX	647	152	XX	369
Other	24 3/	XX	48 3/	83	XX	228
Total	401	XX	1,690	841	XX	2,600
Waste and scrap:						
Canada	108	XX	130	207	XX	168
Other	38	XX	42	122	XX	109
Manganese dioxide:						
Australia	16,300	XX	22,900	19,500	XX	27,400
Belgium	1,030	XX	1,810	976	XX	1,680
Brazil	819	XX	1,110	254	XX	349
Ireland	8,070	XX	11,500	6,970	XX	9,730
South Africa	305	XX	416	801	XX	1,130
Other	289	XX	605	396	XX	954
Total	26,800	XX	38,300	28,900	XX	41,300
Potassium permanganate:						
China	284	XX	157	1	XX	1
Czech Republic	491	XX	886	631	XX	1,190
Germany	99	XX	186	181	XX	310
India	288	XX	456	181	XX	301
Spain	396	XX	831	420	XX	1,020
Other	338 3/	XX	414 3/	42	XX	81
Total	1,900	XX	2,930	1,460	XX	2,900

XX Not applicable. r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes U.S. Geological Survey's conversion of part of reported data (from apparent MnO2 content to Mn content).

3/ Revised; unspecified group of countries differs from that in the 1995 Annual Report.

Source: Bureau of the Census, adjusted by the U.S. Geological Survey.

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TABLE 8
MANGANESE ORE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	Range percent Mn e/ 4/	Gross weight				
		1992	1993	1994	1995	1996 e/
Australia 5/	37-53	1,251	2,092	1,920 e/	2,177 r/	2,109 6/
Brazil 7/ 8/	30-50	1,703 r/	1,837	2,100 r/	2,105 r/	2,200
China e/ 9/	20-30	5,300	5,860	3,570	6,900 r/	6,000
Gabon 7/ 10/	45-53 r/	1,556	1,290	1,436	1,934 r/	2,000
Georgia e/ 7/	29-30	500 r/	300 r/	150 r/	100 r/	97
Ghana 7/	30-50	276	295	270	176	436 6/
India 7/ 11/	10-54	1,810	1,655	1,632	1,764 r/	1,740
Kazakstan e/ 7/ (crude ore)	20-30 r/	400 r/	400 r/	400 r/	428 r/	430
Mexico 7/ 12/	27-50	407	363	307	472 e/	485 6/
South Africa 7/ 10/	30-48 +	2,464	2,507	2,851	3,199	3,240 6/
Ukraine 7/	30-35	5,819	3,800	2,979	3,200	3,000
Other 13/	XX	280	376 r/	414 r/	563 r/	533
Total	XX	21,800 r/	20,800 r/	18,000 r/	23,000 r/	22,300

Country 3/	Range percent Mn e/ 4/	Metal content				
		1992	1993	1994	1995	1996 e/
Australia 5/	37-53	596	1,043	944 e/	1,066	1,023 6/
Brazil 7/ 8/	30-50	664 r/	716	819 r/	821 r/	858
China e/ 9/	20-30	1,060	1,170	714	1,380 r/	1,200
Gabon 7/ 10/	45-53 r/	718	595	663	893 r/	923
Georgia e/ 7/	29-30	148 r/	89 r/	44 r/	30 r/	29
Ghana 7/	30-50	106	115	108	69	174
India 7/ 11/	10-54	687	628	620	670 r/	659
Kazakstan e/ 7/ (crude ore)	20-30 r/	98 r/	98 r/	98 r/	105 r/	106
Mexico 7/ 12/	27-50	153	135	112	174	173 6/
South Africa 7/ 10/	30-48 +	1,080	1,080	1,210	1,350	1,381 6/
Ukraine 7/	30-35	1,850	1,350	1,050	1,100	1,020
Other 13/	XX	101	135	139 r/	200 r/	186
Total	XX	7,260 r/	7,150 r/	6,520 r/	7,860 r/	7,730

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 4, 1997. Data pertain to concentrates or comparable shipping product, except that in a few instances the best data available appear to be for crude ore, possibly after some upgrading.

3/ In addition to the countries listed, Burkina Faso, Cuba, Panama, and Sudan may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels.

4/ May be average content of each year's production rather than for content of typical products.

5/ Metallurgical ore.

6/ Reported figure.

7/ Gross weight reported; metal content estimated and rounded to three significant digits.

8/ Production of beneficiated ore as reported in Sumário Mineral (Brasilia).

9/ Includes manganiferous ore.

10/ Calculated metal content includes allowance for assumed moisture content.

11/ Much of India's production grades below 35% Mn; average content was reported as approximately 38% Mn for fiscal years 1990-91 and 1991-92.

12/ Mostly oxide nodules; may include smaller quantities of direct-shipping carbonate and oxide ores for metallurgical and battery operations.

13/ Category represents the combined totals of Argentina (low-grade ore), Bolivia, Bosnia and Herzegovina, Botswana, Bulgaria, Burma (Myanmar), Chile, Colombia, Egypt, Greece, Hungary, Indonesia, Iran, Italy (from wastes), Japan (low-grade ore), Malaysia, Morocco, Namibia, Philippines, Romania, Thailand, Turkey, and Zambia.

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TABLE 9
FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons, gross weight)

Country	1992					1993				
	Ferromanganese			Silico-manga-nese	Grand total	Ferromanganese			Silico-manga-nese	Grand total
	Blast furnace	Electric furnace	Total			Blast furnace	Electric furnace	Total		
Argentina	--	5	5	31	35	--	5	5	19	24
Australia e/	--	55	55	75	130	--	75	75	75	150
Belgium e/	--	25	25	--	25	--	25	25	--	25
Brazil	--	179	179	300	479	--	202	202	284	486
Chile	--	7	7	2	9	--	9	9	2	11
China e/	550	200	750	420	1,170	520	220	740	525	1,270
Croatia e/	--	10	10	15	25	--	10	10	40	50
Czechoslovakia e/ 3/ 4/	--	70	70	--	70	XX	XX	XX	XX	XX
Egypt e/	--	10	10	--	10	--	30	30	--	30
France 5/	280 e/	60	340	80	420	300	57	357	80	437
Georgia e/	--	100	100	50	150	--	100	100	50	150
Germany e/ 3/ 6/	130	30	160	--	160	100	20	120	--	120
India e/	--	198	198	93	291	--	137 7/	137 7/	85 7/	222 7/
Indonesia e/	--	--	--	--	--	--	10	10	--	10
Italy	--	17	17	50	67	--	17	17	50 e/	67
Japan	--	362	362	96	458	--	383	383	65	448
Kazakstan e/	--	--	--	--	--	--	--	--	--	--
Korea, North e/ 3/	--	70	70	--	70	--	70	70	--	70
Korea, Republic of	--	86	86	83	168	--	101	101	82	183
Mexico	--	79	79	51	130	--	70 e/	70 e/	55 e/	125 e/
Norway	--	203	203	213	416	--	226	226	219	445
Philippines e/	--	5	5	--	5	--	5	5	--	5
Poland	43	5	48	25 e/	73 e/	56	1	58	25 e/	83 e/
Romania e/	--	27	27	28	55	--	16	16	22	38
Russia e/	200	--	200	--	200	150	--	150	--	150
Slovakia e/	XX	XX	XX	XX	XX	--	22	22	12	34
South Africa	--	270	270	267	536	--	393	393	268	661
Spain e/	--	50	50	40	90	--	40	40	35	75
Taiwan	--	38	38	4	42	--	14	14	--	14
Thailand	--	1	1	4	5	--	(8/)	(8/)	2	2
Ukraine e/	50	250 r/	300 r/	1,100 r/	1,400 r/	40	140 r/	180 r/	735 r/	915 r/
United Kingdom	137	--	137	--	137	45	--	45	--	45
Venezuela e/	--	9	9	32	41	--	--	--	42	42
Zimbabwe	--	--	--	--	--	--	2	2	--	2
Total	1,390	2,420 r/	3,810 r/	3,060 r/	6,870 r/	1,210	2,400 r/	3,610 r/	2,770 r/	6,380 r/

See footnotes at end of table.

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TABLE 9--Continued
FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons, gross weight)

Country	1994					1995				
	Ferromanganese			Silico-manga-nese	Grand total	Ferromanganese			Silico-manga-nese	Grand total
	Blast furnace	Electric furnace	Total			Blast furnace	Electric furnace	Total		
Argentina	--	8 r/	8 r/	29 r/	37 r/	--	6 r/	6 r/	27 r/	33 r/
Australia e/	--	100	100	100	200	--	110 r/	110 r/	100 r/	210
Belgium e/	--	25	25	--	25	--	25	25	--	25
Brazil	--	200	200	248	448	--	130 e/	130 e/	167 e/	297 e/
Chile	--	9 e/	9 e/	2	10 e/	--	9 e/	9 e/	2 e/	10 e/
China e/	567	350	917	657	1,570	400 r/	605 r/	1,010 r/	830 r/	1,840 r/
Croatia e/	--	10	10	30	40	--	10	10	30	40
Czechoslovakia e/ 3/ 4/	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Egypt e/	--	35	35	--	35	--	35	35	--	35
France 5/	294	66	360	75 e/	435 e/	304 r/	100 r/	404 r/	80 e/	484 r/ e/
Georgia e/	--	10	10	40	50	--	5	5	25	30
Germany e/ 3/ 6/	--	20	20	--	20	--	20	20	--	20
India e/	--	150	150	140	290	--	150	150	120 r/	270 r/
Indonesia e/	--	10	10	--	10	--	14	14	7	21
Italy	--	16 e/	16 e/	40 e/	56 e/	--	16 e/	16 e/	40 e/	56 e/
Japan	--	345	345	69	414	--	347	347	65	412
Kazakstan e/	--	--	--	40	40	--	--	--	20	20
Korea, North e/ 3/	--	70	70	--	70	--	70	70	--	70
Korea, Republic of	--	120	120	89	209	--	119 e/	119 e/	98 e/	217 e/
Mexico	--	67 e/	67 e/	64 e/	131 e/	--	58	58	68	126
Norway	--	249	249	197	446	--	225 e/	225 e/	200 e/	425 e/
Philippines e/	--	5	5	--	5	--	5	5	--	5
Poland	66 r/	-- r/	66 r/	25 e/	91 r/ e/	46 r/	-- r/	46 r/	25 e/	71 r/ e/
Romania e/	--	31	31	35	67	--	28 7/	28 7/	57 7/	86 7/
Russia e/	55	--	55	--	55	55	--	55	1 r/	56 r/
Slovakia e/	--	25	25	12	37	--	25	25	12	37
South Africa	--	591	591	290	881	--	507 r/	507 r/	251 r/	758 r/
Spain e/	--	35	35	35	70	--	25	25	50 r/	75 r/
Taiwan	--	7	7	--	7	--	5 e/	5 e/	--	5 e/
Thailand	--	(8/)	(8/)	1	1	--	(8/) e/	(8/) e/	1 e/	1 e/
Ukraine e/	30	170 r/	200 r/	600 r/	800 r/	25 r/	170 r/	195 r/	600 r/	795 r/
United Kingdom	--	--	--	--	--	--	--	--	--	--
Venezuela e/	--	--	--	40	40	--	--	--	40	40
Zimbabwe	--	--	--	--	--	--	--	--	--	--
Total	1,010 r/	2,720 r/	3,740 r/	2,860 r/	6,590 r/	830 r/	2,820 r/	3,650 r/	2,910 r/	6,560 r/

See footnotes at end of table.

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TABLE 9--Continued
FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons, gross weight)

Country	1996 e/				
	Ferromanganese			Silico-manga-nese	Grand total
	Blast furnace	Electric furnace	Total		
Argentina	--	6	6	28	34
Australia e/	--	110	110	95	205
Belgium e/	--	25	25	--	25
Brazil	--	160	160	210	370
Chile	--	9	9	2	10
China e/	400	550	950	800	1,750
Croatia e/	--	10	10	30	40
Czechoslovakia e/ 3/ 4/	XX	XX	XX	XX	XX
Egypt e/	--	35	35	--	35
France 5/	300	80	380	80	460
Georgia e/	--	5	5	15	20
Germany e/ 3/ 6/	--	20	20	--	20
India e/	--	150	150	120	270
Indonesia e/	--	14	14	7	21
Italy	--	16	16	50	66
Japan	--	343 7/	343 7/	76 7/	419 7/
Kazakstan e/	--	--	--	50	50
Korea, North e/ 3/	--	70	70	--	70
Korea, Republic of	--	126	126	83	209
Mexico	--	69 7/	69 7/	93 7/	162 7/
Norway	--	225	225	200	425
Philippines e/	--	--	--	--	--
Poland	45	--	45	25	70
Romania e/	--	20	20	79	99
Russia e/	55	--	55	--	55
Slovakia e/	--	25	25	12	37
South Africa	--	480	480	250	730
Spain e/	--	25	25	50	75
Taiwan	--	5	5	--	5
Thailand	--	(8/)	(8/)	1	1
Ukraine e/	30	190	220	650	870
United Kingdom	--	--	--	--	--
Venezuela e/	--	--	--	40	40
Zimbabwe	--	--	--	--	--
Total	830	2,770	3,600	3,040	6,640

e/ Estimated. Revised. XX Not applicable.
1/ Table includes data available through June 25, 1997.
2/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
3/ Data for ferromanganese includes silicomanganese, if any.
4/ Dissolved Dec. 31, 1992.
5/ Includes silicospiegeleisen, if any.
6/ Data for blast furnace ferromanganese includes spiegeleisen, if any.
7/ Reported figure.
8/ Less than 500 tons.

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MERCURY

By Jozef Plachy

Mercury is the only common metal that is liquid at room temperature. It is a corrosion-resistant metal that melts at -38.87°C (-37.97°F) and boils at 356.58°C (673.84°F). Mercury has uniform volumetric thermal expansion, good electrical conductivity, and easily forms amalgams with almost all common metals except iron. It occurs either as native metal or in cinnabar, corderoite, livingstonite, and other minerals.

Since 1990, primary mercury production in the United States has been a byproduct of gold mining, mostly in California, Nevada, and Utah. Most domestic mercury production in 1996 was of secondary origin, derived from recycled mercury-containing devices. Although several companies were engaged in mercury-refining, the three largest were in the eastern and central United States. The value of mercury used in the United States was estimated at $2.8 million. Domestic consumption in 1996 continued to decrease, as mercury is gradually eliminated from products in favor of less toxic substances. About one-third of domestic consumption was used in the production of chlorine and caustic soda. Imports of mercury declined in 1996, following a large increase in 1995 that had been caused by a suspension of sales from the National Defense Stockpile in July 1994. Exports of mercury continued to decline for the fourth consecutive year. *(See table 1.)*

Legislation and Government Programs

On May 13, 1996, the President signed into law legislation affecting mercury-containing and other types of rechargeable batteries. The new law is entitled *The Mercury-Containing and Rechargeable Battery Management Act of 1996* (Public Law 104-142). Title I of the act prohibits the sale of regulated batteries after May 1997 without a label indicating recyclability or proper disposal of these batteries. Title I also empowers the Environmental Protection Agency to streamline the regulatory requirements so that the collection and recycling programs by industry or local governments can be efficient and cost-effective. Title II of the act phases out the use of alkaline-manganese and zinc-carbon batteries containing intentionally added mercury and button cell mercuric-oxide batteries. Other mercury-oxide batteries are allowed if the manufacturer identifies a collection site or telephone number to get information about recycling or disposal. Title II also authorizes EPA to exempt any new use of restricted batteries if safeguards exist against disposal in an incinerator or landfill.

On December 4, 1996, the U.S. Coast Guard signed an agreement with the Georgia Environmental Protection Division to remove from Georgia's waterways discarded zinc-air batteries containing mercury. These batteries were used in Coast Guard Aids to Navigation Stations or lighted navigation beacons. From 1960 through 1980, as these facilities were being serviced, the disposable batteries were sometimes dumped overboard by servicemen, jettisoned by vandals, or sunk during accidental collisions with vessels. The cleanup requires Coast Guard and Navy frogmen to sift through ocean and river sediments, collect all the discarded batteries, and transport them to a reclamation site. The final phase, sediment sampling, will determine if any site remediation is necessary (American Metal Market, 1997a).

Production

Domestic primary mercury was produced, solely as a byproduct, at six gold mines in California, Nevada, and Utah. *(See table 2.)* Reported mine production has been withheld in this report to avoid disclosing company proprietary data.

Whereas most of the world production of mercury is primary (newly mined), nearly all the mercury produced in the United States is derived from secondary sources. Recycling of mercury increased after the development of land disposal restrictions on mercury-containing waste. Because of these restrictions on the disposal of mercury-containing products of all kinds, including mine waste, secondary mercury has become a more cost-effective alternative to primary mercury. Common secondary sources include spent batteries, mercury vapor and fluorescent lamps, switches, dental amalgams, measuring devices, control instruments, and laboratory and electrolytic refining wastes. The secondary processors typically use high-temperature retorting to recover mercury from compounds and distillation to purify the contaminated liquid mercury metal. Refining of recycled mercury in 1996 was dominated by three companies: Bethlehem Apparatus Co., Hellertown, PA; D.F.G. Mercury Corp., Evanston, IL; and Mercury Refining Co., Albany, NY.

In Minnesota, State law prohibits the disposal of thermostats and other mercury-containing devices unless the mercury has been removed. The State also requires that manufacturers of mercury-containing devices provide incentives to induce purchasers to properly dispose of used devices. In response to this legislation, Honeywell Inc., a major manufacturer of thermostats, started a recycling program in which every replaced thermostat is returned to a wholesaler who sends it to Bethlehem Apparatus Co. In 1996, Honeywell began sending postage-paid envelopes with lined bubble packs to homeowners who requested them. Encouraged with 13,000 responses, the company will extend the program to five additional States in 1997 (American Metal Market, 1996b).

As recycling has become a profitable enterprise, an

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increasing number of new companies are entering the mercury-recycling business and established companies are intensifying their recycling efforts. The National Electrical Manufacturers Association, together with three manufacturing companies, formed Thermostat Recycling Corp. to launch an expanded recycling program for mercury switches and thermostats. The goal of the company is eventually to run a national program to recycle all mercury-containing devices. It is estimated by industry specialists that by the year 2000, mercury contamination resulting from the disposal of fluorescent lamps to municipal solid waste will reach 37 tons. To tap into this secondary source, Greenlites Lamp Recycling Inc., of Utica, MI, was constructing a recycling facility for fluorescent, mercury vapor, metal halide, and sodium lamps. The plant was expected to be completed by January 1997. Envirolight Inc. of Riviera Beach, FL, saw its recycling business increase tenfold because of the enactment of tighter disposal restrictions in Florida (American Metal Market, 1996c).

Consumption

Domestic consumption of mercury has been trending downward since the early 1970's. The largest total use of mercury in 1996, the electrolytic production of chlorine and caustic soda in mercury cells, consuming about 0.4 kilogram of mercury per ton of chlorine production, accounted for 136 metric tons. After an increase in 1995, caused by increased use of mercury per unit of production, the overall use of mercury was being reduced by new technology and more efficient on-site mercury reclamation from recycled wastewater sludges. Three U.S. companies are planning to replace old mercury cells with new membrane cells in 1997. The second largest use of mercury was in the electrical industry, mainly for wiring devices and switches. Mercury switches are being replaced in most cases with electronic switches or special switches used in particular niche applications. In fluorescent lighting, where no economically viable alternative to mercury vapor exists, mercury content is being reduced. Light bulbs produced today contain 60% less mercury than those manufactured 10 years ago. However, reduced use of mercury per lamp has been largely negated by an increase in the number of lamps in use, a consequence of the high energy efficiency of fluorescent lighting. The use of mercury in electrical batteries has declined precipitously from more than 1,000 tons annually in the early 1980's to a small fraction of 1 ton in 1996. Alkaline button cell batteries, the only remaining consumer batteries that contain added mercury, are being replaced with zinc-air cells that use less than 1% by weight of mercury. The only mercury oxide batteries that are still produced are for military and medical equipment only, but even for these, research in the development of acceptable substitutes is continuing.

In dental practice, the overall mercury use has remained steady, because it is the most cost-effective and longest lasting dental cavity-filler.

Prices

The average domestic dealer price increased in 1996, the third consecutive annual increase, in response to the tighter market situation. Mercury is usually sold by the 34.5-kilogram (76-pound) flask. The Platt's Metals Week average price for 1996 was $262 per flask, a nearly 6% increase over the 1995 price.

World Review

Spain's Minas de Almadén y Arrayanes (MAA) remained the largest mercury producer in the world. The plant, which over the years has produced about 260,000 tons of mercury, has an annual capacity of about 3,500 tons. Because mercury's popularity has waned with concerns over environmental and health hazards, production in 1996 was only 1,380 tons. During the next 2 years, in addition to the already ongoing improvement of the plant, MAA plans to open a new underground mine, reopen the old underground mine, and extend its open pit El Entredicho Mine. The newly discovered Nuevo Entredicho deposit, which contains an average of 23% mercury, will replace the nearly depleted El Entredicho Mine and the underground Las Cuevas Mine. The mines, present and future, and plant are all located in the Province of Ciudad Real, about 300 kilometers southwest of Madrid. In addition, the state-owned MAA is considering a recycling plant, but it faces an uphill struggle to obtain the necessary permit (Metal Bulletin Monthly, 1996).

The Kyrgyzstan Government has decided to privatize the Government-owned 650-ton-capacity Khaydarkan mining complex by opening its ownership to foreign investors. The mining complex, in southern Kyrgyzstan, consists of underground and open pit mines, a concentration plant, and a metallurgical plant. Khaydarkan produced 380 tons of mercury in 1995 and 580 tons in 1996, plus antimony and fluorite. The increased production was based mainly on selective mining of high-grade ore. Since its opening, Khaydarkan has produced 29,820 tons of mercury, 200,200 tons of fluorite, and an undetermined amount of antimony. In the move to privatize, the State Committee for Reorganization and Liquidation of Enterprises reportedly had to overcome the reluctance of the local government to accept responsibility for social services that the Khaydarkan complex had provided, and liability for old debts owed to other state-owned enterprises. Privatization of the Khaydarkan complex was funded by the World Bank (Mining Journal, 1997a).

Current Research and Technology

The EPA standard for treatment of mercury-containing waste is based on the level of concentration of mercury. Roasting and retorting was determined as the best demonstrated available technologies for mercury-containing sludges having total mercury concentrations above 260 milligrams per kilogram of waste. Applicable technologies for the low-concentration mercury wastes were stabilization, amalgamation,

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electrodialysis, electrowinning, ion exchange, or acid leaching followed by sulfide precipitation.

New technologies for removal of mercury contaminants, based on the classical thermal processes of roasting and retorting, were introduced in 1996. One variation is the medium-temperature thermal process that removes and recovers mercury from soils and industrial waste, invented and developed by Pittsburgh Mineral & Environmental Technology Inc. in Pennsylvania. The process was being tested at a copper smelter where it reportedly reduced residual mercury in the acid plant sludge to less than 1 part per million. This new patented process was marketed by Mercury Recovery Services, Inc., New Brighton, PA (Mining Journal, 1997b).

The DeHg[SM] process, developed by Nuclear Fuel Services, Inc., begins with the sorting and shredding of waste materials containing mercury and other metals specified under the Resources Conservation and Recovery Act (RCRA). Shredded waste is slurried with water, then mixed with reagents to immobilize the mercury. The slurry is later dewatered and packed for shipment to a licensed landfill for disposal. Typical concentration of mercury is less than 0.05 milligram per liter of waste (mg/L), well below RCRA standard of 0.2 mg/L, or 0.2 part per million. The process was claimed by the company to be suitable for remediation of mixed waste containing both radioactive and hazardous metals (Nuclear Fuel Service, Inc., 1997).

Outlook

Ever stricter environmental policy and the advancement of new technology are increasingly affecting both primary and secondary mercury production and mercury's use. Because of the displacement of mercury from products and processes, secondary mercury will become an even more important component of domestic supply, especially if the ban on Government sales of mercury continues. The dismantling of mercury cells in three choralkali operations in the United States, now planned, would enhance the availability of secondary mercury.

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Mercury. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820.

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TABLE 1
SALIENT MERCURY STATISTICS 1/

(Metric tons, unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Producing mines	9	9	7	8	6
Mine production, byproduct	64	W	W	W	W
Secondary production:					
Industrial	176	350	466	534	446
Government 2/	103	--	--	--	--
Shipments from the National Defense stockpile 3/	267	543	86	(4/)	--
Imports for consumption	92	40	129	377	340
Exports	977	389	316	179	45
Industry stocks, yearend 5/	436	384	469	321 r/	446
Industrial consumption	621	558	483	436	372
Price: New York, average per flask	$201.39	$187.00	$194.45	$247.39	$261.61
World: Mine production	1,960 r/	1,800 r/	1,980 r/	3,160 r/	2,890 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits, except prices.

2/ Secondary mercury shipped from U.S. Department of Energy stocks.

3/ Primary mercury.

4/ Revised to zero.

5/ Stocks at consumers and dealers only. Mine stocks withheld to avoid disclosing company proprietary data.

TABLE 2
BYPRODUCT MERCURY-PRODUCING MINES IN THE UNITED STATES IN 1996

Mine	County and State	Operator
Alligator Ridge	White Pine, NV	Placer Dome U. S.
Carlin Mines Complex	Eureka, NV	Newmont Gold Co.
Getchell	Humboldt, NV	FMC Gold Co.
McLaughlin	Napa, CA	Homestake Mining Co.
Mercur	Tooele, UT	Barrick Mercur Gold Mines Inc.
Pinson Mine	Humboldt, NV	Pinson Mining Co.

TABLE 3
U.S. INDUSTRIAL CONSUMPTION OF REFINED MERCURY METAL, BY USE e/ 1/

(Metric tons)

SIC code	Use	1995	1996
28	Chemical and allied products:		
2812	Chlorine and caustic soda manufacture	154	136
36	Electrical and electronic uses:		
3641	Electric lighting	30	29
3643	Wiring devices and switches	84	49
38	Instruments and related products:		
382	Measuring and control instruments	43	41
3843	Dental equipment and supplies	32	31
--	Other uses 2/	93	86
	Total	436	372

e/ Estimated.

1/ The input of refined liquid mercury to domestic manufacturing establishments.

2/ Comprises unclassified uses and those uses from the three principal end-use categories for which the figures are withheld to protect company proprietary data, or for which the volume of use is small.

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TABLE 4
U.S. TRADE IN MERCURY AND MERCURY-BEARING WASTE AND SCRAP, BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Imports:				
Canada	107	$232	137	$791
Germany	3	51	(2/)	20
Japan	19	46	(2/)	3
Kyrgyzstan	45	128	33	266
Russia	179	636	79	302
Spain	14	57	68	327
Other	10	37	23	92
Total	377	1,190	340	1,800
Exports:				
Brazil	5	29	3	16
Canada	3	22	4	29
Germany	17	47	4	25
Hong Kong	52	188	--	--
India	33	93	--	--
Japan	1	18	13	15
Korea, Republic of	3	18	5	50
Mexico	3	60	3	26
Netherlands	5	33	--	--
Venezuela	15	67	--	--
Other	42	195	13	183
Total	179	770	45	344

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than ½ unit.

Source: Bureau of the Census.

TABLE 5
MERCURY: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria	476	459	414	292	300
China e/	580	520	470	780 r/	240
Czechoslovakia 3/ 4/	60	XX	XX	XX	XX
Finland	75 r/	101 r/	90 r/	90 e/	90
Kyrgyzstan	350 r/ e/	350 r/ e/	379 r/	380 r/	580
Mexico	21	12	10 e/	15 e/	15
Morocco e/ 5/	20	20	20	20	20
Russia e/	70	60	50	50	50
Slovakia e/ 4/	XX	50	50	50	20
Slovenia e/	7	--	--	--	--
Spain	36	64 r/	393	1,497	1,500
Tajikistan e/	100	80	55	50	45
Turkey	5	--	--	--	--
Ukraine e/	100	80	50	40	30
United States 6/	64	W	W	W	W
Total	1,960 r/	1,800 r/	1,980 r/	3,160 r/	2,890

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total." XX Not applicable.
1/ Table includes data available through Apr. 29, 1997.
2/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
3/ Dissolved Dec. 31, 1992.
4/ All production in Czechoslovakia for 1992 came from Slovakia.
5/ Mercury was produced only as a byproduct of silver mining.
6/ Mercury was produced only as a byproduct of gold mining.

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MICA

By James B. Hedrick

Mica is a group of phyllosilicate minerals that have a layered or platy texture. The commercially important micas are muscovite and phlogopite. Composed of tetrahedral-octahedral-tetrahedral layers, the mica group is characterized by partial substitution of aluminum for silicon in the silicate tetrahedron. This substitution in the laminar structure provides charges to bind interlayer univalent and divalent cations, typically potassium, magnesium, calcium, and sodium. Layering in the univalent (potassium, sodium) or "true" micas imparts perfect basal cleavage, allowing crystals to be split into very thin sheets that are tough and flexible. Layering in the divalent or "brittle" micas also imparts perfect basal cleavage; however, the greater bond strengths make them more brittle and less flexible.

The value of mica is in its unique physical properties. The crystalline structure of mica forms minerals that can be split or delaminated into thin sheets that are platy, flexible, elastic, transparent to opaque, resilient, reflective, refractive, dielectric, chemically inert, insulating, lightweight, hydrophilic, nonconductive to heat and electricity, and stable to temperature extremes, electricity, light, and moisture. Muscovite is the principal mica used based on its greater abundance and superior electrical properties. Phlogopite remains stable at higher temperatures and is used in applications where a combination of high heat stability and electrical properties is required. Muscovite and phlogopite are used in both sheet and ground forms.

In 1996, about 97,000 metric tons of scrap and flake mica was produced in the United States, 10% less than that in 1995. (*See table 1.*) Ground mica sales were 103,000 tons valued at $33.6 million, an increase in tonnage of 5%. Essentially all of the sheet mica used in the United States was imported, primarily from India. Consumption of muscovite block mica decreased 11% to 5 tons, valued at $383,000. Consumption of mica splittings increased from 713 tons in 1995 to 859 tons in 1996. After a 7% decrease in 1995, worked and unworked sheet mica exports decreased 11% to 831 tons while the value declined 7% to $11.2 million. The value of 6,330 tons of imports of worked and unworked sheet mica increased 4% to $13.1 million.

Legislation and Government Programs

The calendar year 1996 included the U.S. Government fiscal years for 1996 and 1997. Public Law 104-106, the National Defense Authorization Act for Fiscal Year 1996, was enacted in February 1996. It did not change the previous authorizations for the disposal of specific mica stocks in the National Defense Stockpile (NDS). The National Defense Authorization Act for Fiscal Year 1997, Public Law 104-201, was enacted on September 23, 1996. It did not change the previous authorizations for disposal of specific mica stocks.

Stocks of mica classified as excess to goal at the end of fiscal year 1996 (September 30, 1996) included 1,263,553 kilograms of muscovite block (stained and better), 115,468 kilograms of muscovite film (1st and 2nd qualities), 6,002,010 kilograms of muscovite splittings, and 545,754 kilograms of phlogopite splittings. Phlogopite block in the stockpile is 84,265 kilograms below the goal of 143,570 kilograms. No phlogopite block was purchased during fiscal year 1996. *(See table 2.)*

Production

Domestic mine production data for mica are developed by the U.S. Geological Survey from four separate voluntary surveys. Of the 11 operations to which the *Crude Scrap and Flake Mica* production form was sent (excludes low-grade sericite production), 7 operations, or 64%, responded. Of the 16 operations to which the *Ground Mica* form was sent, 14 operations, or 87%, responded, representing 87% of the domestic ground mica production noted in table 1 (excludes low-grade ground sericite production). Of the five surveyed operations to which the *Mica Block and Film* consumption form was sent, three operations, or 60%, responded. Of the nine surveyed operations to which the *Mica Splittings* consumption form was sent, five operations, or 56%, responded. Consumption for the nonrespondents was estimated using prior-year production data. Individual company production and consumption data are withheld to avoid disclosing company proprietary data.

Scrap and Flake Mica.—Eight domestic companies with 11 mines in 5 States produced scrap and flake mica in 1996. The United States was the world's largest producer with 96,600 tons. North Carolina remained the major producing State, with 64% of domestic production. The remainder was produced in Georgia, New Mexico, South Carolina, and South Dakota. Most mica was recovered from mica schist, high-quality sericite schist, weathered pegmatites, and as a coproduct of feldspar, kaolin, and lithium. *(See table 3.)*

The scrap and flake mica producers, in alphabetical order, were Aspect Mineral, Micaville, NC; The Feldspar Corp., Spruce Pine, NC; FMC Corp. Lithium Division, Bessemer City, NC; FMP Division of The Mearl Corp., Hartwell, GA; KMG Minerals Division of Franklin Industries Inc., Kings Mountain, NC and Velarde, NM; K-T Feldspar Corp., Spruce Pine, NC; The Mineral Mining Co., Kershaw, SC; and Pacer Corp., Custer, SD.

Ground Mica.—Nine companies operated 14 grinding

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plants in five States. Ten plants produced dry-ground mica and four plants produced wet-ground mica. The four largest ground mica companies, including one company with four plants, accounted for 74% of the total of 103,000 tons. *(See table 4.)*

Dry-ground mica producers, in alphabetical order, were: Asheville Mica Co., Asheville, NC; KMG Minerals Division of Franklin Industries Inc., Kings Mountain, NC, and Velarde, NM; Mineral Mining Co. Inc., Kershaw, SC; Pacer Corp., Custer, SD; Piedmont Minerals, Hillsborough, NC; Spartan Minerals Corp., a subsidiary of FMC Corp. Lithium Division, Pacolet, SC; and USG Corp., Spruce Pine, NC. Wet-ground mica producers, in alphabetical order, were: Aspect Mineral, Bakersville, NC; the FMP Division of The Mearl Corp., Hartwell, GA, and Franklin, NC; and KMG Minerals Division of Franklin Industries Inc., Kings Mountain, NC.

Consumption

Statistics on domestic mica consumption are developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments.

Sheet Mica.—Sheet mica is used principally in the electronic and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties and its mechanical properties, which allow it to be cut, punched, stamped, and machined to close tolerances.

The largest use of block mica is as an electrical insulator in electronic equipment. High-quality mica is also used to line the gauge glasses of high-pressure steam boilers because of its transparency, flexibility, and resistance to heat and chemical attack. Other uses include diaphragms for oxygen-breathing equipment, marker dials for navigation compasses, optical filters, retardation plates in helium-neon lasers, pyrometers, thermal regulators, and stove and kerosene heater windows. Specialized applications for sheet mica are found in ground and air-launched missile systems, optical instrumentation, laser devices, medical electronics for radiation treatment, radar systems, and aerospace components.

Muscovite film mica is used as a dielectric in capacitors. Only high-quality mica is used in this application. The highest grade film is used in capacitors that are manufactured as calibration standards. The next grade down is used in transmitting capacitors. Receiving capacitors use a slightly lower grade of high-quality muscovite.

Consumption of muscovite block (ruby and nonruby) totaled 4,640 kilograms, an 8% decrease from that of 1995. Stained and lower-than-stained quality remained in greatest demand, accounting for 91.4% of ruby mica block. Consumption of nonruby mica block was spilt 74% for good quality and 26% for stained quality. Block mica use in 1996 was slightly higher than that in 1995.

Five companies continued to consume muscovite block and film in five plants in four States: two in North Carolina and one each in New Jersey, Ohio, and Virginia.

Mica splittings represents the largest part of the sheet mica industry in the United States. Muscovite and phlogopite splittings are used to make built-up mica. Consumption of muscovite and phlogopite splittings increased 20.6% in 1996 to 859 tons. *(See table 6.)* Muscovite splittings from India accounted for more than 95% of domestic consumption. The remainder of consumption was primarily phlogopite splittings imported from Madagascar and muscovite from other countries. The splittings were fabricated into various built-up mica products by nine companies operating nine plants in seven States.

Built-Up Mica.—Produced by mechanical or hand setting of overlapping splittings and alternate layers of binders and splittings, built-up mica is primarily used as an electrical insulation material. Major products are molding plate, segment plate, flexible plate, tape, heater plate, mica paper, and bonding materials. *(See table 7.)*

Segment plate acts as insulation between the copper commutator segments of direct-current universal motors and generators. Phlogopite built-up mica is preferred because it will wear at the same rate as the copper segments. Muscovite has a greater resistance to wear, causing uneven ridges that may interfere with the operation of a motor or generator. Consumption of segment plate was 172 tons in 1996, essentially the same as in 1995.

Molding plate is sheet from which V-rings are cut and stamped for use in insulating the copper segments from the steel shaft ends at the ends of a commutator. Molding plate is also fabricated into tubes and rings for insulation in transformers, armatures, and motor starters. Consumption of molding plate decreased slightly from 181 tons in 1995 to 179 tons in 1996.

Flexible plate is used in electric motor and generator armatures, field coil insulation, and magnet and commutator core insulation. Mica consumption in flexible plate increased from 107 tons in 1995 to 123 tons in 1996.

Heater plate is used where high-temperature insulation is required. Consumption of mica in heater plate declined slightly in 1996.

Tape, powdered mica paper, and silicone and other bonding materials consumption was 139 tons, 3.7% more than that in 1995.

Some types of built-up mica have the bonded splittings reinforced with special paper, silk, linen, muslin, glass, cloth, or plastic. These products are very flexible and are produced in wide, continuous sheets that are either shipped rolled or cut into ribbons, tapes, or trimmed to specified dimensions. Built-up mica products are also corrugated or reinforced by multiple layering.

Total consumption of built-up mica that was consumed or shipped was 633 tons, an increase of 3% from the 1995 level. Segment plate and molding plate were the major end products and accounted for 27% and 28% of the total, respectively.

Reconstituted Mica (Mica Paper).—Primary uses for mica paper are the same as those for built-up mica. Three companies consumed scrap mica to produce mica paper. The principal source of the scrap was India. Manufacturing companies in

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1996 were: Corona Films Inc., West Towsend, MA; General Electric Co., Coshocton, OH; and U.S. Samica Corp., Rutland, VT.

Ground Mica.—The largest domestic use of dry ground mica was in joint compound for filling and finishing seams and blemishes in gypsum wall board (drywall). The mica acts as a filler and extender, provides a smooth consistency, improves the workability of the compound, and imparts resistance to cracking. Joint compound accounted for 54.3% of dry-ground mica consumption.

In the paint industry, ground mica is used as a pigment extender that also facilitates suspension, reduces chalking, prevents shrinking and shearing of the paint film, increases resistance of the paint film to water penetration and weathering, and brightens the tone of colored pigments. Mica also promotes paint adhesion in both aqueous and oleoresinous formulations. Consumption of dry-ground mica in paint, its second largest use, accounted for 18.2% of the 1996 total.

Ground mica is used in the well-drilling industry as an additive to drilling muds. The coarsely ground mica flakes help prevent loss of circulation by sealing porous sections of the drill hole.

The rubber industry uses ground mica as an inert filler and as a mold release compound in the manufacture of molded rubber products such as tires and roofing. The platy texture acts as an antiblocking, antisticking agent. Rubber mold lubricant accounted for 3.2% of dry-ground mica use in 1996.

The plastics industry uses dry-ground mica as an extender and filler, especially in parts for automobiles for lightweight insulation to suppress sound and vibration. Mica is used in plastic automobile fascia and fenders as a reinforcing material, providing improved mechanical properties, increased strength, stiffness, and dimensional stability. Mica-reinforced plastics also have high-heat dimensional stability, reduced warpage, and the best surface properties of any filled plastic composite. Consumption of dry-ground mica in plastic applications accounted for 3.5% of the market in 1996, slightly lower than the 3.9% in 1995.

Ground mica is used in the production of rolled roofing and asphalt shingles, where it serves as a surface coating to prevent sticking of adjacent surfaces. The coating is not absorbed by freshly manufactured roofing because mica's platy structure is unaffected by the acid in asphalt or by weathering conditions. As a rubber additive, mica reduces gas permeation and improves resiliency.

Other uses include decorative coatings on wallpaper, concrete, stucco, and tile surfaces. It is also used as an ingredient in some special greases, as a flux coating on welding rods, and in foundry applications as coatings for core and mold release compounds, mold washes, and facing agents.

Stocks

Government stocks of mica in the NDS is comprised of stockpile-grade muscovite block, stained and better; muscovite film, first and second quality; muscovite splittings; phlogopite block; and phlogopite splittings. NDS stocks of muscovite block, muscovite film, and muscovite and phlogopite splittings were available for sale from the Defense National Stockpile Center, Fort Belvoir, VA. Yearend 1996 stocks of various types of mica in the NDS are shown in table 2.

Reported yearend industry stocks of muscovite mica block (ruby and nonruby) decreased from 26.4 tons in 1995 to 21.5 tons in 1996. Industry stocks of muscovite and phlogopite mica splittings decreased from 466 tons at yearend 1995 to 416 tons at yearend 1996. *(See table 6.)*

Prices

Sheet mica prices vary with grade and can range from less than $1 per kilogram for low-quality mica to more than $2,000 per kilogram for the highest quality. The average values of muscovite sheet mica consumed in the United States in 1996 compared with 1995 were as follows: block (ruby and nonruby) increased 5% to $77 per kilogram and muscovite splittings decreased 4% to $1.63 per kilogram.

The average value of phlogopite block decreased to $19.84 per kilogram, while the average value of phlogopite splittings decreased $0.05 to $4.40 per kilogram. Changes in average value for block and splitting are more a reflection of the quality of sheet mica consumed during the year than actual changes in prices.

The average U.S. value of crude flake mica, including high-quality sericite, increased to $81 per ton. The average value for North Carolina flake mica increased to $80 per ton in 1996.

In 1996, the value of dry-ground mica increased slightly to average $182 per ton while wet-ground mica also increased to average $1,032 per ton.

World Review

Following an average year in 1995, the mica market in the United States declined in 1996. Foreign trade was mixed with the value of U.S. exports of mica declining 4.5% to $14.8 million as the quantity increased 2.6% to 8,371 tons. Imports of mica decreased with the value of U.S. exports of mica, declining 5.1% in value to $22.6 million and the quantity declining 5.3% to 24,800 tons. *(See table 13.)*

Domestic ground mica imports decreased to 5,830 tons, down 450 tons from the 1995 level. Exports of crude and rifted mica increased, up 97.6% to 1,395 tons. *(See table 8.)* Exports of worked mica sheet in 1996 declined 17.8% to 606 tons. *(See table 9.)* The value of U.S. exports of worked mica sheet decreased to $10.7 million, 8.9% lower than that in 1995.

The United States continued to rely on imports, primarily from India, for essentially all of its supply of sheet mica and paper-quality scrap mica. Imports for consumption of unmanufactured split block, film, and splittings were about 5,102 tons, 82% more than that in 1995 *(See table 10.)*

About 13,600 tons of ground mica was imported in 1996, mostly from Canada. *(See table 11.)* Worked mica imports

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were 5% lower than those in the previous year, at 1,092 tons. *(See table 12.)*

Outlook

The outlook for mica is for average growth of 3% to 5% based on various economic factors. The major markets for ground mica, joint compounds and paints, are mature and relatively stable, and growth is tied to new housing starts and interest rates. To a lesser extent, widespread natural disasters also effect the market, creating immediate demand for residential building materials. Demand is also responsive to automobile production because interior and exterior parts typically contain dry-ground mica, while exterior surfaces are painted with wet-ground pearlescent pigments and mica-containing coatings.

In 1997 and 1998, domestic demand for crude and ground mica is expected to remain stable. Demand for dry-and wet-ground micas is expected to improve in the short term to meet increasing demand for pearlescent paints and cosmetics. Markets for dry-ground mica are forecast to grow 5%t per year through the year 2000, unless interest rates rise sufficiently to slow demand for new housing and automobiles. Wet-ground mica is also expected to show moderate growth as demand from the cyclical automotive industry utilizes increasing amounts of pearlescent paint pigments.

Demand for block mica is expected to grow slowly through the end of the century as demand increases in a few specialty markets. A shortage of high-quality block mica is expected to continue because of the generally low percentage of high-quality mica in currently mined deposits (pegmatites).

Consumption of mica splittings, the major type of sheet mica consumed in the United States, decreased sharply throughout the 1960's and 1970's and leveled off in the 1980's and 1990's in the range of 800 to 1,000 tons per year. With no new uses and many substitute materials, no substantial growth is expected. Consumption of mica splittings is expected to remain in the range of 600 to 900 tons.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines

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TABLE 1
SALIENT MICA STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Production (sold or used by producers):						
Scrap and flake mica	thousand metric tons	85	88	109	108	97
Value	thousands	$4,640	$4,450	$5,780	$5,630	$7,820
Ground mica	thousand metric tons	84	92	95	98	103
Value	thousands	$21,800	$27,000	$28,700	$24,800	$33,600
Prices, dollars per metric ton:						
Scrap and flake mica		$55	$51	$53	$52	$81
Ground:						
Wet		$745	$838	$1,010	$974 r/	$1,000
Dry		$168	$152	$151	$174 r/	$182
Sheets, dollars per kilogram:						
Block		$80	$95	$66 r/	$73 r/	$77
Splittings		$1.53	$1.55	$1.72 r/	$1.86 r/	$1.75
Consumption:						
Block, muscovite	metric tons	6	5	6	5	5
Value	thousands	$447	$509	$432	$407	$383
Splittings	metric tons	836	826	857	713	859
Value	thousands	$1,390	$1,390	$1,470	$1,320	$1,510
Exports	metric tons	5,040	5,860	7,520	8,160	8,380
Imports	do.	18,800	22,200	25,200	26,200	24,700
World: Production	do.	205,000	197,000	238,000	253,000 r/	225,000 e/

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits.

TABLE 2
STOCKPILE STATUS AND GOVERNMENT INVENTORIES FOR MICA, DECEMBER 31, 1996 1/

(Metric tons)

	Inventory			
Material	Stockpile grade	Nonstockpile grade	Available for disposal	1996 sales
Block:				
Muscovite, stained and better	1,390	12	1,310	--
Phlogopite	8	--	--	--
Film: Muscovite, 1st and 2d qualities	391	--	96	276
Splittings:				
Muscovite	6,000	--	6,000	234
Phlogopite	307	--	307	226

1/ Data are rounded to three significant digits.

TABLE 3
SCRAP AND FLAKE MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

	1995		1996	
State	Quantity	Value	Quantity	Value
North Carolina	74	3,690	62	4,900
Other States 3/	34	1,940	35	2,920
Total	108	5,630	97	7,820

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes finely divided mica recovered from mica schist and high-quality sericite schist, and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.
3/ Includes Georgia, New Mexico, South Carolina, and South Dakota.

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TABLE 4
GROUND MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY END USE AND METHOD OF GRINDING 1/ 2/

	1995			1996		
	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value	Quantity (thousand metric tons)	Value (thousand dollars)	Unit value
End use:						
Joint cement	45	6,420	$142	52	8,610	$165
Paint	19	3,780	198	21	8,850	421
Plastics	4	1,380	344	3	1,970	656
Well-drilling mud	5	582	116	4	815	203
Other 3/	25	12,700	506	23	13,400	581
Total	98	24,800	253	103	33,600	326
Method of grinding:						
Dry	W	W	158	W	W	165
Wet	W	W	884	W	W	936

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Domestic and some imported scrap. Low-quality sericite is not included.
3/ Includes mica used for molded electrical insulation, roofing, rubber, textile and decorative coatings, welding rods, and miscellaneous.

TABLE 5
FABRICATION OF MUSCOVITE BLOCK MICA IN THE UNITED STATES, BY QUALITY 1/

(Metric tons)

Quality	1995	1996
Good stained or better	0.692	0.590
Stained or lower 2/	3.910	4.490
Total	4.600	5.070

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes punch mica.

TABLE 6
CONSUMPTION AND STOCKS OF MICA SPLITTINGS IN THE UNITED STATES 1/

	Consumption		Stocks on
Year	Quantity (metric tons)	Value (thousands)	Dec. 31 (metric tons)
1995	713	$1,320	466
1996	859	1,510	416

1/ Data are rounded to three significant digits.

TABLE 7
BUILT-UP MICA SOLD OR USED IN THE UNITED STATES, BY PRODUCT 1/ 2/

	1995		1996	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Flexible (cold)	107	$566	123	$1,020
Heater plate	W	W	W	W
Molding plate	181	1,590	179	1,710
Segment plate	172	W	172	1,990
Tape	W	W	W	W
Other	125	943	126	972
Total	614	4,890	633	6,110

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Consists of alternating layers of binder and irregularly arranged and partly overlapped splittings.

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TABLE 8
U.S. EXPORTS OF CRUDE AND RIFTED MICA, MICA POWDER, AND WASTE IN 1996, BY COUNTRY 1/

Country	Crude and rifted: Less than $0.55 per kilogram		Crude and rifted: More than $0.55 per kilogram		Powder		Waste	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	--	--	--	--	50	$62	--	--
Australia	19	$7	1	$11	121	90	--	--
Barbados	--	--	--	--	7	7	--	--
Belgium	--	--	--	--	14	53	--	--
Brazil	--	--	81	63	11	7	--	--
Canada	31	7	--	--	3,170	1,310	541	$118
Chile	209	73	--	--	27	20	--	--
Colombia	--	--	--	--	60	41	--	--
Cote d'Ivoire	--	--	--	--	(2/)	9	--	--
France	24	8	--	--	77	127	--	--
Germany	621	183	2	35	15	84	--	--
Hong Kong	36	13	--	--	--	--	--	--
India	--	--	21	45	17	27	--	--
Ireland	15	5	--	--	--	--	--	--
Israel	15	5	--	--	--	--	--	--
Italy	--	--	--	--	51	11	--	--
Jamaica	--	--	--	--	20	22	--	--
Japan	7	3	5	39	431	283	--	--
Korea, Republic of	40	19	1	3	388	312	--	--
Malaysia	--	--	--	--	114	15	--	--
Mexico	--	--	1	9	507	207	--	--
Netherlands	--	--	106	235	--	--	--	--
New Zealand	--	--	--	--	528	143	--	--
Nicaragua	--	--	2	5	--	--	--	--
Norway	--	--	3	66	--	--	--	--
Peru	--	--	--	--	10	9	--	--
Romania	--	--	--	--	8	90	--	--
Singapore	--	--	1	13	--	--	--	--
Spain	10	3	(2/)	5	(2/)	6	--	--
Sweden	8	3	--	--	18	11	--	--
Taiwan	--	--	--	--	59	46	--	--
Thailand	23	8	--	--	--	--	--	--
United Arab Emirates	--	--	--	--	17	12	--	--
United Kingdom	15	5	1	14	1	13	--	--
Uruguay	--	--	--	--	5	8	--	--
Venezuela	99	35	--	--	106	48	--	--
Total	1,170	377	225	542	5,830	3,070	541	118

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 9
U.S. EXPORTS OF WORKED MICA IN 1996, BY COUNTRY 1/

Country	Plates, sheets		Other	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	4	$68	17	$126
Austria	--	--	(2/)	4
Bahamas, The	12	36	12	49
Barbados	9	100	--	--
Belgium	23	618	(2/)	10
Belize	--	--	(2/)	3
Brazil	11	131	2	118
Canada	107	2,660	59	1,370
Chile	3	19	(2/)	4
China	(2/)	4	(2/)	3
Colombia	3	17	(2/)	11
Costa Rica	13	61	4	18
Dominica	--	--	(2/)	3
Dominican Republic	1	6	(2/)	20
Ecuador	1	3	--	--
El Salvador	2	4	--	--
France	2	76	(2/)	19
Germany	1	10	(2/)	29
Guatemala	4	18	2	9
Honduras	(2/)	3	1	29
Hong Kong	2	61	1	58
India	45	357	18	493
Ireland	--	--	1	19
Italy	26	557	1	14
Jamaica	4	17	4	54
Japan	10	117	50	392
Korea, Republic of	1	7	(2/)	16
Malaysia	--	--	1	20
Mexico	35	785	21	920
Netherlands	--	--	2	32
Netherlands Antilles	1	3	1	7
Pakistan	--	--	(2/)	4
Peru	(2/)	10	--	--
Philippines	--	--	(2/)	3
Russia	--	--	44	248
Saudi Arabia	5	38	(2/)	3
Singapore	4	37	1	14
South Africa	2	38	(2/)	17
Suriname	2	12	--	--
Sweden	(2/)	3	(2/)	9
Switzerland	(2/)	21	6	178
Taiwan	11	168	2	81
United Kingdom	2	65	3	83
Venezuela	4	30	--	--
Total 2/	352	6,170	254	4,490

1/ Data are rounded to three significant digits; may add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND RIFTED MICA IN 1996, BY COUNTRY 1/

Country	Split block		Splittings		Other			
					Less than $0.55 per kilogram		More than $0.55 per kilogram	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	--	--	68	$11	--	--	(2/)	$2
China	--	--	9	21	--	--	126	266
Finland	--	--	--	--	997	$299	--	--
France	1	$6	3	19	--	--	(2/)	2
Germany	--	2	360	73	--	--	--	--
Hong Kong	--	--	--	--	--	--	3	13
India	101	124	4,360	1,640	3,360	654	2	48
Japan	--	--	--	--	--	--	1	17
Korea, Republic of	--	--	--	--	--	--	3	2
Madagascar	--	--	2	9	--	--	--	--
Singapore	--	--	201	30	--	--	--	--
Taiwan	--	--	--	--	--	--	4	15
United Kingdom	--	--	(2/)	2	--	--	(2/)	9
Total	102	132	5,000	1,810	4,360	953	138	375

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF MICA POWDER AND WASTE IN 1996, BY COUNTRY 1/

Country	Powder		Waste	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	1	$1	--	--
Canada	13,000	5,100	(2/)	$4
China	16	34	--	--
Finland	1	9	--	--
France	3	2	--	--
Germany	41	180	--	--
India	--	--	446	231
Japan	376	2,740	--	--
Korea, Republic of	12	9	--	--
Madagascar	--	--	36	37
Malaysia	35	109	--	--
Mexico	20	2	--	--
Norway	16	11	--	--
United Kingdom	4	58	--	--
Total	13,600	8,250	482	272

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF WORKED MICA IN 1996, BY COUNTRY 1/

Country	Plates, sheets		Other	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	--	--	1	$15
Austria	--	--	1	22
Belgium	443	$4,530	--	--
Brazil	50	652	41	110
Canada	24	284	--	--
China	145	350	24	118
France	32	243	10	105
Germany	8	400	9	479
Hong Kong	--	--	1	8
India	89	700	74	693
Italy	--	--	1	21
Japan	7	72	18	348
Korea, Republic of	8	51	20	44
Russia	--	--	1	3
Singapore	13	290	--	--
Spain	(2/)	5	--	--
Sweden	(2/)	6	--	--
Switzerland	40	848	--	--
Taiwan	(2/)	8	--	--
United Kingdom	21	375	(2/)	7
Venezuela	12	29	--	--
Total	892	8,840	200	1,970

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 13
SUMMATION OF U.S. MICA TRADE DATA 1/

	Scrap and flake mica				Sheet mica			
	Powder		Waste		Unworked		Worked	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Exports:								
1995	6,280	$3,160	952	$294	198	$389	737	$11,700
1996	5,830	3,070	1,710	495	225	542	606	10,700
Imports for consumption:								
1995	14,200	9,280	7,730	1,880	3,080	1,950	1,150	10,700
1996	13,600	8,250	4,840	1,230	5,240	2,310	1,090	10,800

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

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TABLE 14
MICA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina:					
Sheet	373	720	720 e/	700 e/	700
Waste, scrap, etc.	635	1,226	1,104 r/	4,341 r/	4,000
Brazil e/	7,000	7,000	7,000	7,000	7,000
Canada e/	17,500	17,500	17,500	17,500	17,500
France e/	12,000 4/	8,000	8,000	10,000	8,000
India:					
Crude	2,742	2,082	2,055 r/	1,721 r/	2,000
Scrap and waste	1,522	1,187	719 r/	767 r/	750
Total	4,264	3,269	2,774 r/	2,488 r/	2,750
Iran e/ 5/	7,846 4/	8,000	8,000	8,000	8,000
Korea, Republic of (all grades)	7,732	7,500 e/	37,470	43,704	35,923 4/
Madagascar (phlogopite)	798	774 e/	774 e/	432 r/	450
Malaysia	4,754	4,659	4,993	5,848	5,501 4/
Mexico (all grades)	5,866	6,440	5,753	5,028 r/	5,030 4/
Morocco e/	1,500	1,500	1,500	1,500	1,500
Peru e/	100	100	100	100	100
Russia e/	35,000	30,000	25,000	25,000	20,000
Serbia and Montenegro	281	68	158 r/	199 r/	200
South Africa (scrap)	2,079	1,991	1,973	2,137	1,429 4/
Spain e/	200	250	200	200	200
Sri Lanka (scrap) e/	200	200	200	200	200
Taiwan	11,038	9,751	5,220	9,792 r/	9,000
United States (scrap and flake) 6/	85,300	87,900	109,000	108,000	96,600 4/
Zimbabwe	495	500	213 e/	1,040 r/	1,000
Grand total	205,000	197,000	238,000	253,000 r/	225,000

e/ Estimated. r/ Revised.

1/ World data, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 22, 1997.

3/ In addition to the countries listed, China, Norway, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

5/ Year beginning Mar. 21 of that stated.

6/ Excludes U.S. production of low-quality sericite and sheet mica, if any.

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MOLYBDENUM

By John W. Blossom

Molybdenum is a refractory metallic element used principally as an alloying agent in steels, cast irons, and superalloys to enhance hardenability, strength, toughness, and wear and corrosion resistance. To achieve desired metallurgical properties, molybdenum, primarily in the form of molybdic oxide or ferromolybdenum, is frequently used in combination with/added to chromium, columbium, manganese, nickel, tungsten, or other alloy metals. The versatility of molybdenum has ensured it a significant role in contemporary industrial technology, which increasingly requires materials that are serviceable under higher stresses, greater temperature ranges, and more corrosive environments. Moreover, molybdenum finds significant usage as a refractory metal in numerous chemical applications, including catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitutions, has resulted in a demand that is expected to grow at a greater rate than most other ferrous metals.

Distribution of molybdenum reserves and productive capacity is concentrated in a few countries of the world. World mine output was an estimated 128,000 metric tons (molybdenum contained in concentrate), of which Canada, Chile, China, and the United States provided 65%. These four countries, led by the United States, are expected to continue to be the principal mine producers for the rest of this century. These countries also possess about 90% of the estimated 12 million metric tons of molybdenum in world reserve base.

Domestic production data for molybdenum are derived by the USGS by means of three separate voluntary surveys. These surveys are Molybdenum Ore and Concentrate (annual), Molybdenum Concentrate (monthly), and Molybdenum Products and Molybdenum Concentrates (monthly). Surveys are sent to all operations that produce molybdenum ore and products. All 14 operations to which surveys were sent responded, representing 100% of the total U.S. production shown in table 1.

Domestic mine production of molybdenum concentrate decreased to 54,900 tons of contained molybdenum, compared with 60,900 tons in 1995. This production was about 43% of world production. World mine production of molybdenum concentrate decreased from a total of 141,000 tons in 1995 to 128,000 tons. Production of molybdenum products was the same as in 1995. *(See tables 1, 2, and 3.)*

Consumption

Consumption of molybdenum concentrate decreased by 1,000 tons. Domestic mine production of molybdenum concentrate was either roasted, exported for conversion, or purified to lubrication-grade molybdenum disulfide. The consumption in 1996 of technical-grade molybdic oxide increased about 3% from that of 1995. Oxide is the chief form of molybdenum used by industry, particularly in stainless and alloy steel, cast irons, and superalloys. Some of the material is, however, also converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder. *(See table 2.)*

Stocks

Total industry stocks, which include those of producers and consumers, decreased by about 1,600 tons of contained molybdenum. Inventories of molybdenum in concentrate at producer locations decreased about 2,920 tons. Producer stocks of molybdenum in products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, increased by about 960 tons. Domestic end-use consumer stocks of molybdenum increased 310 tons from that of 1995. Inventories of 10,800 tons represented about a 28-week supply, as measured by reported consumption.

Prices

Prices are from Platt's Metals Week (1996) and are in U.S. dollars per kilogram of contained molybdenum. The prices at the beginning of 1996 were molybdenum concentrates (MoCons), $6.172; molybdic oxide (MoX), $9.590; and ferromolybdenum (Femo), $12.952. The prices at the beginning of the second quarter were MoCons, $4.684; MoX, $8.157; and Femo, $11.574. The prices at the start of the third quarter were MoCons, $4.409; MoX, $7.385; and Femo, $10.251. The prices at the start of the fourth quarter were MoCons, $6.062; MoX, $11.574; and Femo, $12.456. The prices at the end of the fourth quarter were MoCons, $4.960; MoX, $9.479; and Femo, $11.464. The average prices were MoCons, $5.026; MoX, $8.291; and Femo, $11.248.

Foreign Trade

Exports of molybdenum in concentrate and in molybdic oxide were about the same as those of 1995; molybdenum concentrate exports were about 82% of domestic mine production. About 96% of reported exports went to Belgium, Chile, China, Japan, Mexico, the Netherlands, and the United Kingdom. The calculated molybdenum content of all exports was about 49,700 tons. Total value of exports decreased from $707 million in

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1995 to $301 million.

About 20,700 tons of molybdenum in various forms were imported into the United States, about 2,400 tons more than in 1995. Total value of all forms of molybdenum imported decreased from $188 million in 1995 to $132 million. In terms of value, the major form imported was ferromolybdenum. *(See tables 5, 6, and 7.)*

World Review

Capacity.—As of December 31, 1996, the rated capacity for mines and mills was 125,000 tons per year of contained metal. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Reserves.—With a reserve base of molybdenum estimated at 5.4 million tons, the United States has 45% of the world molybdenum reserve base. About 90% of U.S. reserves are in large porphyry or disseminated deposits mined, or anticipated to be mined, primarily for molybdenum; these deposits are in Alaska, Colorado, Idaho, Nevada, New Mexico, and Utah. Other molybdenum sources contribute insignificantly to U.S. reserves.

Most Canadian reserves of molybdenum are in British Columbia. Other Canadian reserves are associated with molybdenum and copper-molybdenum porphyry deposits in British Columbia and with minor sources in New Brunswick and Quebec.

Molybdenum reserves in Central America and South America are associates mainly with large copper porphyry deposits. Of several such deposits in Chile, the Chuquicamata and the El Teniente deposits are among the world's largest and account for 85% of total reserves in Chile. Mexico and Peru have substantial reserves. The La Caridad deposit in Mexico is a large producer. Numerous other copper porphyries that may contain recoverable quantities of molybdenum have been identified in Central America and South America. Many of these deposits are being actively explored and evaluated and could substantially add to reserves in the future.

Reserves of molybdenum in China and the former Soviet Union are estimated to be substantial, but definitive information about the current sources of supply or prospects for future development in the two countries is lacking.

Outlook

The world demand for molybdenum contained in alloy and stainless steel and also for chemicals/catalysts is expected to increase about 3% in 1997. It is estimated that the demand in 1998 will be about the same as in 1997.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT MOLYBDENUM STATISTICS 1/

(Metric tons of contained molybdenum unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Concentrate:					
Production	49,700	36,800	46,800	60,900	54,900
Shipments	43,100 r/	39,200	40,000 r/	61,700	57,900
Value thousands	$190,000	$165,000	$284,000	$651,000	$456,000
Reported consumption	15,200	13,800	17,200	25,500 r/	24,500
Imports for consumption	831	3,400	2,280	5,570	5,480
Stocks, Dec. 31:					
Concentrate, mine and plant	11,900	11,200	5,510	5,390	2,470
Product producers 2/	7,480	6,150	3,940	4,820	5,780
Consumers, by end use	2,500	2,510 r/	2,080	2,210	2,520
Total	21,900	19,900	11,500	12,400	10,800
Primary products:					
Production	26,000	22,700	31,100	46,000	46,300
Shipments	17,300	16,000	21,400	24,000	24,100
Reported consumption, by end use	17,200	17,700	19,100	19,900 r/	20,300
World: Mine production	114,000 r/	99,500 r/	112,000 r/	141,000 r/	128,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes technical and purified molybdic oxide, briquets, ferromolybdenum, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, sodium molybdate, calcium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF MOLYBDENUM PRODUCTS IN THE UNITED STATES 1/

(Metric tons of contained molybdenum)

	1995	1996	1995	1996	1995	1996
	Metal powder		Other 2/		Total	
Received from other producers	--	--	3,380	4,140	3,380	4,140
Gross production during year	4,680	4,830	41,300	41,500	46,000	46,300
Molybdenum products used to make other products	2,710	2,850	20,400	21,000	23,100	23,900
Net production	1,970 r/	1,970	20,900	20,400	22,900 r/	22,400
Shipments	452	481	23,500	23,600	24,000	24,100
Producer stocks, Dec. 31	221	223	4,590	5,560	4,820	5,780

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes ferromolybdenum, molybdic oxides, phosphomolybdic acid, molybdenum disulfide, molybdic acid, ammonium molybdate, calcium molybdate, sodium molybdate, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

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TABLE 3
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained molybdenum)

Country 3/	1992	1993	1994	1995	1996 e/
Armenia e/	1,000	500	500	800	900
Canada	9,405	9,700	10,250	9,113 r/	8,845 p/
Chile	14,500 r/	14,899	16,028	17,889	18,000
China e/	19,200	18,300	21,400 r/	32,000 r/	25,000
Iran e/	1,320 4/	1,000	1,000	1,200	1,200
Kazakstan e/	700	600	500	700	800
Korea, Republic of	5	--	2	-- r/	--
Mexico	1,458	1,705	2,610	3,810	3,900
Mongolia	1,610	2,050	2,100	1,830	2,200 4/
Peru	3,220	2,980	2,765	3,411 r/	3,711 4/
Russia e/	10,800 r/	10,300 r/	7,700 r/	8,800 r/	8,500
United States	49,700	36,800	46,800	60,900	54,900 4/
Uzbekistan e/	700	700	700	500	500
Total	114,000 r/	99,500 r/	112,000 r/	141,000 r/	128,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 13, 1997.

3/ In addition to the countries listed, North Korea, Romania, and Turkey are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

4/ Reported figure.

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TABLE 4
U.S. REPORTED CONSUMPTION OF MOLYBDENUM, BY END USE 1/

(Kilograms, contained molybdenum)

End use	Molybdic oxides	Ferro-molybdenum 2/	Ammonium and sodium molybdate	Molyb-denum scrap	Other 3/	Total
1995:						
Steel:						
Carbon	604,000 r/	301,000	--	--	76,500	982,000 r/
Stainless and heat-resisting	3,230,000	344,000	--	--	74,800	3,650,000
Full alloy	2,450,000 r/	1,180,000 r/	--	--	45,200	3,680,000 r/
Electrical	--	W	--	--	--	W
High-strength, low-alloy	628,000 r/	298,000 r/	--	--	--	926,000 r/
Tool	1,080,000	W	--	--	28,600	1,110,000
Unspecified steel	W	W	--	--	2,100	2,100
Cast irons	214,000 r/	772,000 r/	--	--	14,100 r/	1,000,000 r/
Superalloys	W r/	W	--	W	547,000 r/	547,000 r/
Alloys:						
Welding materials (structural and hard facing)	--	86,600	--	W	6,770	93,300 r/
Other alloys 4/	W	W	--	--	79,000	79,000 r/
Mill products made from metal powder	--	W	--	--	2,200,000	2,200,000
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	1,710,000	--	W	--	179,000	1,890,000
Other	W	--	W	--	290,000	290,000 r/
Miscellaneous and unspecified	1,180,000 r/	387,000 r/	1,260,000	451,000	146,000 r/	3,430,000 r/
Total	11,100,000 r/	3,370,000 r/	1,260,000	451,000	3,690,000 r/	19,900,000 r/
1996:						
Steel:						
Carbon	597,000	316,000	--	--	76,500	990,000
Stainless and heat-resisting	3,460,000	343,000	--	--	77,600	3,880,000
Full alloy	2,740,000	1,540,000	--	--	46,300	4,320,000
Electrical	--	W	--	--	--	W
High-strength, low-alloy	470,000	377,000	--	--	--	848,000
Tool	1,080,000	89,600	--	--	32,200	1,200,000
Unspecified steel	W	24,900			1,370	26,200
Cast irons	177,000	905,000	--	--	27,800	1,110,000
Superalloys	W	57,000	--	W	479,000	536,000
Alloys:						
Welding materials (structural and hard facing)	--	88,700	--	W	6,320	95,000
Other alloys 4/	W	W	--	--	73,800	73,800
Mill products made from metal powder	--	W	--	--	2,050,000	2,050,000
Chemical and ceramic uses:						
Pigments	W	--	W	--	--	W
Catalysts	1,700,000	--	W	--	179,000	1,880,000
Other	W	--	W	--	305,000	305,000
Miscellaneous and unspecified	1,160,000	66,200	1,130,000	513,000	121,000	2,990,000
Total	11,400,000	3,810,000	1,130,000	513,000	3,480,000	20,300,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes calcium molybdate.

3/ Includes purified molybdenum disulfide, molydenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

4/ Includes magnetic and nonferrous alloys.

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TABLE 5
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS NO.	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Belgium		133	$2,070	45	$398
Brazil		1	16	--	--
Canada		1,160	12,800	848	5,820
India		2	28	--	--
Japan		345	6,360	582	4,780
Korea, Republic of		3	28	--	--
Mexico		121	2,700	79	1,060
Netherlands		909	15,700	210	1,860
Spain		153	2,210	--	--
United Kingdom		--	--	21	77
Venezuela		8 r/	121 r/	--	--
Other		9	142	1	3
Total		2,840	42,200	1,790	14,000
Molybdates all, contained weight:	2841.70.0000				
Argentina		--	--	(2/)	3
Australia		9	301	11	135
Brazil		34	408	3	54
Canada		377	2,640	395	2,290
China		4	66	21	191
Colombia		9	92	16	100
Honduras		2	28	2	26
Japan		144	2,810	159	1,610
Korea, Republic of		111 r/	1,800	70	668
Mexico		59 r/	328	68	349
Netherlands		1,220	26,300	260	1,590
Singapore		28	153	8	49
South Africa		18	183	18	115
Taiwan		23	193	80	194
Thailand		1	39 r/	211	175
Venezuela		116	390 r/	--	--
Other		28 r/	217 r/	15	60
Total		2,180 r/	36,000	1,340	7,620
Ferromolybdenum, contained weight: 3/	7202.70.0000				
Australia		1 r/	25	--	--
Canada		214 r/	3,740	420	2,900
Japan		105 r/	2,300	214	1,870
Korea, Republic of		2 r/	30	3	40
Malaysia		22 r/	1,270	62	252
Mexico		201 r/	4,040	192	1,610
Netherlands		74 r/	1,880	--	--
Singapore		(4/)	(4/)	89	3,220
Spain		23 r/	581 r/	1	17
Taiwan		48 r/	710	--	--
Venezuela		3 r/	40 r/	1	12
Other		2 r/	22 r/	3	3
Total		695 r/	14,600	985	9,930
Powder, gross weight:	8102.10.0000				
Brazil		7	286	3	102
Canada		19 r/	405	5	171
France		11	419 r/	11	330
Germany		95	3,200	9	555
India		32	957	32	1,110
Italy		(2/) r/	39 r/	(2/)	46
Japan		81 r/	3,610	74	2,930
Mexico		6	272 r/	3	149
Netherlands		3	135 r/	--	--
Spain		3	187 r/	2	131
Sweden		28	860 r/	4	130
Switzerland		--	33 r/	--	--
Taiwan		1	49 r/	4	94
United Kingdom		13	439	6	430
Other		7 r/	218 r/	57	2,080
Total		306 r/	11,100	210	8,260

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY 1/

Product and country	HTS NO.	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Molybdenum unwrought, gross weight:	8102.91.0000				
Australia		--	--	9	$219
Austria		58	$927	12	191
Brazil		(2/)	6	30	510
Canada		32 r/	702	26	698
China		62	633	52	650
France		(2/)	12	23	404
Germany		31 r/	579	38	665
India		7	183	23	390
Japan		375	4,550	324	2,800
Korea, Republic of		(2/)	15	--	--
Mexico		1 r/	19 r/	6	52
Netherlands		38 r/	1,780	39	214
Sweden		--	--	(2/)	16
United Kingdom		8	115	13	266
Other		17 r/	250 r/	6	29
Total		629 r/	9,770 r/	601	7,110
Molybdenum wrought, gross weight:	8102.92.0000				
Brazil		1	50	3	119
Canada		18	795	24	859
France		11	569	8	493
Germany		5	480	3	394
India		(2/)	26	1	447
Italy		(2/)	17	(2/)	42
Japan		72	6,970	74	4,750
Korea, Republic of		3	217	8	634
Mexico		(2/)	70	1	137
Netherlands		(2/)	78	4	181
United Kingdom		62	2,840	47	2,420
Other		10 r/	563 r/	12	505
Total		182 r/	12,700	185	11,000
Wire, gross weight:	8102.93.0000				
Argentina		(2/)	29	(2/)	45
Belgium		1	123	(2/)	17
Brazil		27	1,220	32	1,640
Canada		4	229 r/	1	69
France		28	1,510	14	806
Germany		56	3,250	19	1,280
Hungary		44	2,840	36	4,030
India		10	756	9	587
Indonesia		2	138	2	110
Italy		19	1,080	8	443
Japan		24	1,830	14	1,160
Korea, Republic of		14	963	8	472
Mexico		2	212	1	137
Netherlands		(2/) r/	25 r/	--	--
Singapore		4	205	--	--
South Africa		3	200	1	60
Spain		1	72	1	67
Sweden		23	1,330	9	450
Taiwan		17	1,030	5	293
United Kingdom		10	427	5	349
Other		14 r/	263 r/	9	280
Total		303 r/	17,700	174	12,300

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Ferromolybdenum contains about 60% to 65% molybdenum.
4/ Revised to zero.

Source: Bureau of the Census.

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TABLE 6
U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED AND OTHER CONCENTRATES), BY COUNTRY 1/

(Metric tons)

Country	1995 Quantity (contained molybdenum)	1995 Value (thousands)	1996 Quantity (contained molybdenum)	1996 Value (thousands)
Australia	65	$597	61	$588
Belgium	10,300	123,000	12,400	48,200
Brazil	157	2,740	20	138
Canada	759	9,640 r/	268	1,880
Chile	6,290	59,400	6,990	35,400
China	--	--	1,290	4,480
Germany	769	12,000	505	2,800
India	--	--	59	262
Italy	137	1,960 r/	384	2,370
Japan	5,490	86,300	5,140	31,900
Korea, Republic of	(2/)	3	10	135
Mexico	4,040	40,200	5,500	22,700
Netherlands	11,200	153,000	5,890	36,600
Sweden	636 r/	9,530 r/	473	4,190
Switzerland	32	680	--	--
United Kingdom	4,740	64,700	6,010	40,100
Other	14	187 r/	26	131
Total	44,600	564,000 r/	45,000	232,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM 1/

Item	HTS No.	1995 Gross weight (metric tons)	1995 Contained molybdenum	1995 Value (thousands)	1996 Gross weight (metric tons)	1996 Contained molybdenum	1996 Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	7,430 r/	4,780	$73,000	8,090	5,460	$40,900
Molybdenum ore and concentrates, other	2613.90.0000	1,500	793	7,990	36	21	169
Molybdenum oxides and hydroxides	2825.70.0000	918	NA	11,200	1,160	NA	8,670
Molydates of ammonium	2841.70.0000	345	185	2,810	665	368	5,230
Molybdates all others	2841.70.5000	54 r/	42 r/	279 r/	83	36	486
Molybdenum orange	3206.20.0000	673 r/	NA	2,250	1,840	NA	5,670
Mixtures of inorganic compounds	3823.90.3400	1 r/	(2/) r/	128 r/	1	1	214
Ferromolybdenum	7202.70.0000	6,550	4,190	73,700	7,870	4,960	54,300
Molybdenum powders	8102.10.0000	195	146	5,470	125	110	3,360
Molybdenum unwrought	8102.91.1000	131	102	3,430	91	84	2,360
Molybdenum waste and scrap	8102.91.5000	453	429	6,230	693	640	9,480
Molybdenum wire	8102.93.0000	1 r/	NA	272 r/	2	NA	309
Molybdenum other	8102.99.0000	3	NA	970	4	NA	1,030
Total		18,300 r/	10,700 r/	188,000 r/	20,700	11,700	132,000

r/ Revised. NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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NICKEL

By Peter H. Kuck

On August 21, 1996, Inco Limited acquired Diamond Fields Resources Inc. for $3.1 billion. The acquisition gave Inco control of the immense Voisey's Bay nickel-copper-cobalt deposit in Labrador. The deposit was discovered in 1993 and is the most significant Canadian base metal find in more than 30 years. Exploration drilling, which is still in the early stages, already has delineated four ore zones, with indicated resources totaling at least 150 million metric tons of sulfide ore. The Voisey's Bay project, the modernization of operations at Sudbury, Ontario, and the new Raglan Mine in northern Quebec should solidify Canada's position as a leading supplier of nickel far into the 21st century.

Russia, the world's largest producer of nickel, continued to privatize and restructure all of its nickel mining and smelting operations. In 1996, RAO Norilsk Nickel accounted for 93% of total Russian production. Modernization of the company's three smelters has been hampered by the enormous amounts of capital required. Efforts were underway to borrow a significant portion of the necessary funds from potential financial backers in Scandinavia.

In December 1994, Sherritt Inc. and the Government of Cuba formed a joint venture to refine and market nickel mined at Moa. Since then, Sherritt has undergone a restructuring, changed its name to Viridian Inc., and spun off its holdings in the joint nickel venture. The divested company, Sherritt International Corp., continued to modernize the Moa operation. The bulk of the sulfide precipitate was being shipped to Sherritt International's refining complex at Fort Saskatchewan, Alberta.

The price of nickel metal on the London Metal Exchange (LME) declined gradually during 1996, bottoming out in December at $6,581 per metric ton ($2.985 per pound). The monthly average for December 1995 had been $8,091 per metric ton ($3.670 per pound). The decline in price occurred even though producers' stocks in the Western World declined at the same time from 98,700 tons to 85,000 tons. Also, stocks in LME warehouses never exceeded 50,000 tons and were far below the record high of 151,254 tons reached on November 24, 1994, when the price was $7,625 per metric ton ($3.459 per pound).

World nickel supplies continued to keep pace with the growing demand for the metal. Mine development or expansion projects were underway in Brazil, Indonesia, Manitoba, New Caledonia, Ontario, Quebec, Venezuela, and Western Australia. In addition to Labrador, exploration teams were active in Côte d'Ivoire, Cuba, Finland, Greenland, Russia, South Africa, and Tanzania.

In 1996, apparent U.S. demand for primary nickel was 2% less than that of 1995. U.S. demand for stainless steel, in contrast, was up 4%. About 34% of U.S. stainless demand was being met by imports. U.S. stainless production decreased 9% during the same period. Smaller declines in stainless production were reported by the European Union (-4%) and Japan (-1%) (American Iron and Steel Institute, 1997a; International Nickel Study Group, 1997b).

Stainless steel production remained depressed in Russia because of that country's continuing economic restructuring. In other parts of the world, though, stainless steel production has been steadily growing. Capacity was being added in the Republic of Korea, South Africa, and Taiwan. By 1997, the combined output of austenitic stainless steel from the Republic of Korea and Taiwan is expected to exceed that of North America. Stainless steel now accounts for about 66% of primary nickel demand in the entire world (Anderson, 1996; Upton, 1997). Another 5% is consumed in the production of alloy steels. Over the last 20 years, stainless steel production in the Western World has been growing at an average rate of 4.5%, down somewhat from the long-term trend of 6.0%.

Demand for primary nickel by battery manufacturers continues to grow, although the tonnages involved are an order of magnitude smaller than those for stainless steel. Rechargeable nickel-cadmium and nickel-metal hydride batteries are in strong competition with one another for hand-held power tools, cellular telephones, laptop computers, and camcorders. The bulk of the batteries imported into the United States are made in Japan, Mexico, China, France, or Hong Kong (in descending order of market share).

PSA Peugeot-Citroën and Renault of France began producing electric vehicles (EV's) on an extended basis. The new vehicles were being powered by nickel-cadmium batteries made by SAFT S.A. Honda Motor Co. Ltd. was planning to begin leasing nickel-metal hydride-powered EV's to California fleet owners in 1997.

Legislation and Government Programs

Cuban Embargo.—Relations between Cuban nickel producers and the U.S. Government deteriorated during 1996. Cuba has the largest reserve base of nickel-bearing laterites in the world. Three mining and smelting complexes are currently producing nickel on the island. Nicaro and Punta Gorda produce nickel oxide by the ammonium-carbonate leach process and are operated by La Compania General de Niquel S.A. (General Nickel), a parastatal enterprise (Suttill, 1994). The third, Moa, produces a nickel-cobalt sulfide precipitate which is shipped to Canada for further processing. This third complex is operated as a joint venture of Sherritt International Corp. and

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General Nickel. The Cuban Government and Sherritt are equal partners in the Moa venture. Construction of a fourth plant, Las Camariocas, was suspended about 5 years ago after key Eastern European partners withdrew from the project. All four plants are in Holguín Province. None of the nickel production can be marketed in the United States because of the U.S. embargo against Cuba. Importation of Cuban nickel is prohibited under the Cuban Assets Control Regulations, 31 CFR, part 515. There were also bilateral agreements on this issue between the U.S. Government and several major nickel-consuming nations.

On March 12, 1996, the President signed into law legislation designed to discourage foreign investment in Cuba. The new law was entitled "The Cuban Liberty and Democratic Solidarity (LIBERTAD) Act of 1996" (Public Law 104-114). The LIBERTAD Act codified the existing executive orders that imposed an economic embargo on Cuba. The LIBERTAD Act gives American citizens, whose property was expropriated by the Cuban Government, the right to sue in U.S. courts any foreign company that makes use of the property. In addition, entry into the United States can be denied to foreign corporate officials and other principals found trafficking in expropriated Cuban properties. The European Union responded by taking the whole matter of the Cuban embargo to the newly formed World Trade Organization.

At least two other prominent nickel producers, besides Sherritt, have entered into agreements with Cuban parastatal organizations since 1993. Gencor Limited of South Africa recently began evaluating a lateritic deposit in the San Felipe area of Camaguey Province. In September 1994, Western Mining Corporation Holdings Limited of Australia (now WMC Limited) signed a memorandum of understanding with Commercial Caribbean Nickel S.A. to evaluate and develop the Pinares de Mayari West lateritic deposit in Holguín Province. The Pinares deposit reportedly contains more than 200 million tons of ore exceeding 1% nickel and 0.1% cobalt (Western Mining Corporation Holdings Limited, 1995; WMC Limited, 1997). At least two companies have approached the Government of Cuba about resuming work on the mothballed Las Camariocas project.

Environmental Regulations.—In 1994, legislation was introduced in the Congress to make the reclamation of spent consumer batteries (i.e., household batteries, batteries for portable office equipment, and batteries for EV's) more economically feasible and remove regulatory burdens from the battery recycling industry.

A modified version of the legislation pertaining specifically to spent nickel-cadmium batteries was taken up again by the 104th Congress, passed, and signed into law by the President on May 13, 1996. The new law was entitled "The Mercury-Containing and Rechargeable Battery Management Act of 1996" (Public Law 104-142). Title I of the act established uniform national labeling requirements for nickel-cadmium, small sealed lead-acid, and certain other regulated batteries. Each battery or battery pack must bear a recycling symbol and a recycling phrase appropriate to its electrode chemistries. The labeling requirements are similar to ones already adopted by Japan. Domestic battery manufacturers and importers must be in complete compliance with the labeling requirements by May 1998. Title I also provided for the streamlining of regulations governing battery collection and recycling. Voluntary industry programs are to be encouraged, and regulatory requirements are to be minimized so that the collection and recycling programs can be efficient and cost-effective.

The U.S. Environmental Protection Agency (EPA) is responsible for enforcing most of the provisions of the act. EPA can now promulgate regulations requiring manufacturers of rechargeable consumer products to redesign their products, if safety is not compromised, so that the batteries inside can be more easily removed. The agency also has been directed to work with battery manufacturers, manufacturers of consumer products, and retailers in disseminating proper handling and disposal information on batteries to the general public. The legislation had the support of most battery manufacturers and many retailers. (*See Current Research and Technology section of this review.*)

In 1995, EPA introduced new regulations designed to encourage environmentally sound recycling of nickel-cadmium batteries and keep them out of the municipal waste stream. The new regulations were part of a much larger package of regulations known as the "Universal Waste Rule." At the beginning of 1996, 13 of the 50 States had laws regulating nickel-cadmium and other rechargeable batteries. Nine of the thirteen States also required the collection of rechargeable batteries. The Portable Rechargeable Battery Association, a nonprofit trade association composed of more than 100 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, was in the process of setting up a nationwide collection and recycling system.

Several States, faced with increasing air pollution problems, have taken action on their own to reduce exhaust emissions from automobiles, similar vehicles, and other self-propelled machinery powered by internal combustion engines. The manufacturing and sale of EV's were being encouraged because EV's appear to be at least a partial solution to some of these problems, especially in metropolitan areas. On March 29, 1996, the California Air Resources Board (CARB) unanimously approved a staff recommendation to restructure the board's electric vehicle mandate (Rechtin, 1996; Rose, 1996). The staff recommendation was based in part on the findings of an independent battery technical advisory panel. CARB still wants to have 800,000 EV's and other zero-emission automobiles on California highways by the year 2010. However, the board decided to drop its earlier requirement that seven leading automobile manufacturers begin selling EV's in California in 1998. The manufacturers involved were Chrysler Corp., Ford Motor Co., General Motors Corp., Honda Motor Co., Mazda Motor Corp., Nissan Motor Co., and Toyota Motor Corp. The old regulations would have required 2% of all automobiles sold in California in 1998 to be EV's or some other type of zero-emission vehicle. This percentage was to escalate to 5% beginning with the 2001 model year. The two requirements were dropped after the auto manufacturers requested additional

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time to resolve technological problems. The auto manufacturers are particularly concerned that the limited range of the first generation of EV's will seriously limit their marketability.

In exchange for being released from the 1998 requirement, the manufacturers have agreed to meet the existing 10% requirement for the year 2003 and to begin selling low-emission vehicles—the so-called 49-State car—in the 2001 model year. The board directed its staff to draw up a memorandum of agreement between the State of California and each of the seven auto manufacturers. Special credits will be issued to manufacturers who market EV's before 2003.

Only four battery chemistries were being used in the initial production runs. Chrysler, Ford, and General Motors were all planning to initially use advanced lead-acid battery packs. Honda and Toyota are currently testing nickel-metal hydride packs. General Motors is also considering offering a nickel-metal hydride battery pack as an option on its first mass-marketed EV—the EV1.

Several European EV's could conceivably carve out a niche in the California market. PSA Peugeot Citroën and Renault already have begun to produce nickel-cadmium powered EV's on a large scale in France. In October 1995, SAFT SA inaugurated a nickel-cadmium EV battery plant in Bordeaux, France, that can initially produce 5,000 batteries per year. The International Metals Reclamation Co., Inc. (Inmetco) now has equipment at its Ellwood City facility that can reclaim spent nickel-cadmium and nickel-metal hydride batteries from EV's on a limited basis (Hanewald, Schweers and Liotta, 1996). Deutsche Post AG (the German postal service), Daimler-Benz AG (Mercedes-Benz), and several other northern European enterprises are working together with Electric Fuel Limited of Israel to develop a refuelable zinc-air battery.

The production of only 10,000 nickel-cadmium or nickel-metal hydride powered EV's for the California market would require roughly 1,800 tons of nickel. According to Toyota officials, the nickel-metal hydride battery pack offers 1.5 times the energy storage capacity of lead-acid batteries while being more than 10% lighter (Kimberley, 1995).

On December 13, 1996, the President of the United States signed an Executive order designed to encourage the use of EV's and other alternative fueled vehicles (AFV's) in metropolitan areas of the country (Presidential Documents, 1996). Executive Order 13031 (Federal Alternative Fueled Vehicle Leadership) required each Federal Agency to immediately develop and implement plans for acquiring alternative fueled vehicles. In fiscal year (FY) 1997, 33% of the general-use vehicles acquired were to be AFV's. This percentage increases to 50% in FY 1998, 75% in FY 1999, and 75% for subsequent years. The Executive order was designed to reduce U.S. dependence on imported oil, to provide an economic stimulus to domestic industry, and to improve air quality in various parts of the country. Some industry analysts expect the order will spur production of nickel-metal hydride batteries for EV's in the United States. The effect of the order on the use of enhanced nickel-cadmium batteries in U.S. vehicles was uncertain. No U.S. automobile manufacturer has announced plans to introduce a nickel-cadmium powered automobile in the near future. However, nickel-cadmium batteries are being used in at least two European and one Japanese EV models. Nickel-cadmium batteries offer some advantages over advanced lead competitors in terms of reliability, longevity, energy density, and recyclability. Nickel-cadmium batteries also have the potential to capture a large part of the propulsion market for electric motor scooters, electric bicycles, and electric wheelchairs. Tokyo R&D Co. Ltd. recently began selling a nickel-cadmium powered electric scooter. The scooter retails in Japan for ¥596,000 or about $5,030.

Defense Stockpile Sales.—The Defense Logistics Agency (DLA) continued to sell nickel from the National Defense Stockpile (NDS). The Government had 33,760 tons of nickel in inventory when the sales started on March 24, 1993. All 33,760 tons was some form of electrolytic metal except for 399 tons contained in 520 tons of oxide of Cuban origin. The ongoing sales are part of a much larger downsizing of the stockpile approved under the Defense Authorization Act of 1992 (Public Law 102-484). In 1996, nickel was being offered at monthly auctions and through privately negotiated long-term solicitations.

By the end of 1995, uncommitted stocks had shrunk to 17,010 tons—all of it metal. An additional 2,787 tons was awaiting pickup on December 31, 1995, for a total physical inventory of 19,797 tons. In 1996, DLA warehouses turned over 3,938 tons to purchasers, leaving uncommitted stocks of 10,257 tons on December 31. Total yearend stocks also included 5,602 tons of committed material, for a grand total of 15,859 tons. At the currently authorized rate of sales, the remaining stocks of metal should be exhausted by mid-1999.

Production

The United States has only one primary nickel producer—the Glenbrook Nickel Co. of Riddle, OR. In 1996, Glenbrook produced 15,070 tons of nickel contained in ferronickel—a record high tonnage for the Douglas County operation. The mining and smelting complex is a 50-50 joint venture of Cominco American Inc. and Cominco Resources International Ltd. The smelter has a design capacity of 16,000 tons per year of nickel in ferronickel and uses the Ugine reduction process to make high-grade granulated ferronickel from lateritic ores. The Ugine process requires ferrosilicon, which is added to the molten nickel ore to promote rapid reduction of the nickel while still keeping a large part of the iron in oxide form. Glenbrook's ferronickel has a considerably higher nickel content (48% to 52%) than most competing products (19% to 41%). The company was planning to upgrade the smelter baghouse and dust handling system so that the complex would have more operational flexibility and still fully comply with the air quality permit issued by the State of Oregon (Cominco Ltd., 1997).

Société Minière du Sud Pacifique of New Caledonia has a long-term contract with Glenbrook to supply most of the lateritic ore consumed by the smelter. The imported ore is unloaded at

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Glenbrook's Coos Bay port facility in Coos County and dried at dockside before being trucked to Riddle. The remainder of the smelter feed comes from the company's mine on Nickel Mountain that overlooks the smelter. The nickel content of the New Caledonian ore is significantly higher than that from Nickel Mountain (2.3% vs. 1.25% nickel on a dry basis). At the end of 1996, the Nickel Mountain Mine had only 230,000 tons of reserves remaining. However, additional resources of similar grade are available from other lateritic deposits in Douglas County and neighboring Josephine County. Cominco also has 2.5 million tons of probable resources and 6.0 million tons of possible resources at its Buena Vista deposit in Guatemala. The Guatemalan ore averages 2.2% nickel and, if prices warranted, conceivably could be trucked to Puerto de San José and from there shipped by vessel along the Pacific coast to Coos Bay.

Inmetco, a subsidiary of Inco Limited, continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel from emission control dusts, swarf, grindings, and mill scale—all wastes generated by the stainless steel industry. Because of subsequent improvements to the facility, Inmetco can accept a broad spectrum of other recyclable nickel- and/or chromium-bearing wastes, including filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries. In 1996, Inmetco produced about 21,400 tons of chromium-nickel-iron alloy containing 15,100 tons of iron, 3,400 tons of chromium, 2,600 tons of nickel, and 330 tons of molybdenum from material that would otherwise be disposed of in landfills (The International Metals Reclamation Co., Inc., 1997).

Inmetco now accepts three types of spent nickel-based batteries: nickel-cadmium, nickel-metal hydride, and nickel-iron but asks shippers to segregate the latter two from the nickel-cadmium batteries whenever feasible. Industrial nickel-cadmium batteries are handled differently than their smaller household counterparts. Workers dismantle the industrial batteries using power saws, drain off the electrolyte, and visually segregate the nickel plates from their cadmium counterparts. The nickel plates are shredded and fed directly into the main rotary hearth furnace, while the cadmium plates go into an electric-powered distillation furnace where the cadmium is fumed off. The much smaller, consumer cells have to be shredded and then thermally oxidized to remove their plastic components before they can be charged into the distillation furnace. The nickel and iron-rich residue left in the distillation furnace is later fed into the main chromium-nickel-iron feedstream.

Limited quantities of nickel also were recovered at some copper and precious metals refineries and a few plants that reclaim spent catalysts. The Stillwater Mining Co. was setting up a recovery circuit for nickel-cobalt sulfides at its platinum-group metals concentrator in Columbus, MT.

Consumption

Demand for primary nickel in the Western World weakened slightly and was estimated to be about 838,000 tons—down 7% from the all time high of 900,000 tons reached in 1995 (International Nickel Study Group, 1997a). However, the tonnage was still 7% more than the previous record of 785,000 tons set in 1994 (revised figure). U.S. apparent consumption of primary nickel was 149,100 tons, or about 18% of Western demand. U.S. industry consumed an additional 59,200 tons of nickel in scrap. Both U.S. and world demand continued to be driven by the stainless steel industry, which accounted for 40% of primary nickel demand in the United States and more than 60% of equivalent world demand.

Since 1991, major restructuring, adoption of more efficient work practices, and the introduction of new technology have improved the competitiveness of the U.S. specialty steel industry. Production of raw stainless and heat-resisting steel in the United States decreased slightly to 1.87 million tons and was 9% less than the corresponding record-breaking figure of 2.06 million tons for 1995. Nickel-bearing grades accounted for 1.21 million tons, or 63% of the total stainless production for 1996 (American Iron and Steel Institute, 1997a). Net shipments of all types of stainless totaled 1.73 million tons (American Iron and Steel Institute, 1997b). Shipments of sheets and strip increased 4% to 1.25 million tons, breaking the previous record of 1.20 million tons set in 1995. The next largest category was plate [flat product 4.8 millimeter (3/16 inch) or more in thickness]. Shipments of plate were 220,000 tons, 9% less than that of 1995. Together, plate and sheet accounted for 85% of total net shipments, a slightly higher percentage than in 1995.

Stainless steel sheet is used in the manufacture of a wide range of consumer products, including household appliances, kitchen facilities, machinery, and medical equipment. Plate is primarily used in the fabrication of chemical reaction vessels and similar heavy-duty industrial equipment. The chemical, food and beverage, petrochemical, pharmaceutical, pulp and paper, and textile industries are all large consumers of stainless plate.

In 1996, U.S. consumption of primary nickel in superalloys decreased 7% because of problems in the aerospace industry. Jet engine manufacturers (e.g., General Electric Co., Pratt & Whitney Co., Inc. [subsidiary of United Technologies Corp.], and Rolls-Royce PLC) are significant consumers of nickel-chromium-cobalt and nickel-chromium-iron alloys. The last few years have been difficult for U.S. aerospace companies because of declining defense spending and a protracted airline recession. The aerospace market is now shifting from a government-dominated market to one driven primarily by commercial customers. The U.S. Government now accounts for only 50% of domestic aerospace products and services, compared with 75% a decade ago. Sales by the U.S. aerospace industry rose 8% to $117 billion after falling in 1995 to the lowest level in 9 years (Aerospace Industries Association of America, Inc., 1996).

For the second year in a row, Boeing Co. and McDonnell Douglas Corp. built up their backlog of orders for civil jet transports. A total of 595 net orders for large civil jet transports were received in 1996, compared with 421 in 1995. Actual

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shipments also increased between 1995 and 1996, rising from 256 aircraft to 269. On December 31, 1996, the companies had a combined backlog of 1,617 aircraft, up from 1,291 at yearend 1995. Aerospace sales were expected to rise 11% in 1997 and improve even more in 1998.

In early 1996, Allegheny Ludlum Corp. and Teledyne Inc. agreed to merge (Holusha, 1996; Norton and Pasztor, 1996). Allegheny Ludlum, one of the larger producers of stainless steel in the Western Hemisphere, had been interested in acquiring the specialty metals operations of Teledyne for more than 10 years. Teledyne was, at the time, a conglomerate of defense and consumer products businesses, with strong segments in aviation, electronics, and specialty metals.

The new entity was called Allegheny Teledyne Inc. At yearend 1996, the combined company had a market capitalization of roughly $4 billion and assets of $2.6 billion. Sales totaled $3.8 billion for the year. About 60% of total revenues, or $2.3 billion, came from sales of specialty metals. Another 22% of revenues was generated by sales of equipment and services to the aerospace and electronics industries. The merger took effect on August 15, 1996, following approval by the shareholders of both companies. The new corporation was headquartered in Pittsburgh, PA, together with the specialty metals operations.

The principal force driving the merger was the financial synergies that should be created after the specialty metals operations of the two companies are fully integrated. Allegheny Ludlum accelerated its merger efforts after New York-based WHX Corp. offered to take over Teledyne for $1.2 billion in late 1994. WHX owns Wheeling-Pittsburgh Steel Corp., the ninth largest integrated steel producer in the United States. The last offer made by WHX was $1.78 billion. The merger made Allegheny Teledyne one of the larger specialty metals producers in the world.

Demand for nickel-cadmium and nickel-metal hydride batteries continues to grow throughout all of North America and is being spurred by the rapidly expanding U.S. program for recycling industrial and household batteries. Both battery types are widely used in hand-held power tools and a myriad of portable electronic devices, including compact disc players, pocket recorders, camcorders, cordless telephones, cellular telephones, scanner radios, and laptop computers. The United States imported $673 million worth of nickel-cadmium batteries. The bulk of the imported batteries were made in Mexico, Japan, China, or Hong Kong (in descending order of market share).

Stocks

The combined stocks of primary nickel maintained in the United States by foreign producers and metal-trading companies with U.S. sales offices decreased 12% during the year. At yearend, these stocks represented 27 days of apparent primary consumption.

In recent years, LME stocks have far exceeded U.S. consumer stocks. However, the gap sharply narrowed during the first half of 1996. On December 23, 1996, LME warehouses held 49,548 tons of nickel metal, of which 45,498 tons or 91.8% was in the form of cut cathodes. The remaining 8.2% consisted of 4,014 tons of briquets and 36 tons of pellets. The 49,548-ton total represented a drop of 67% from the all-time record high of 151,254 tons reached on November 24, 1994. Although the LME now has 25 warehouse sites scattered around the world that are authorized to hold nickel, most of the material continues to be stored in Rotterdam.

Prices

Nickel prices peaked in January 1995 at $9,593 per ton ($4.351 per pound) after recovering from a 6-year low in September 1993. Since then, prices have fallen considerably. In 1995, nickel demand in the Western World exceeded supply by approximately 66,000 tons. However, in 1996, the situation was reversed, with supply exceeding demand by about 38,000 tons. The price decline was spurred by massive exports of cathode and carbonyl pellets from Norilsk Nickel. Internal demands within Russia for hard currency and the continued depressed state of the Russian stainless steel industry encouraged Norilsk to export the bulk of its production to the West.

The highest prices were recorded in February, with the monthly LME cash price reaching $8,216 per ton ($3.727 per pound). From then on, prices gradually weakened, eventually dropping to $6,581 per ton ($2.985 per pound) in December. The last weekly price (for the week ending December 27, 1996) was $6,438 per ton ($2.920 per pound). The average annual price was $7,501 per ton ($3.402 per pound). The annual price was about 9% lower than the 1995 average of $8,228 per ton ($3.732 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 59% in 1996—essentially the same percentage as in 1995. Imports accounted for 99% of primary supply in 1996, if Government stockpile sales are excluded. Canada, as usual, supplied most of the imported material. The second largest source was Norway, which has limited mine production and a single refinery—Falconbridge's Nikkelverk operation at Kristiansand. The Norwegian refinery uses Canadian and Botswanan mattes as its principal feedstocks.

Since 1992, Russia also has become an important source of nickel for the United States. U.S. imports of Russian cathode (including pellets) declined 46% in 1996, after jumping by almost a factor of 7 between 1994 and 1995. In 1996, the United States imported 17,221 tons of cathode and 734 tons of powder and/or flake directly from Russia. Importers also brought in 418 tons of Russian nickel contained in ferronickel and 4 tons contained in nickel sulfate.

In 1996, limited cutbacks in stainless steel production in North America and Western Europe caused prices for primary nickel and nickel-bearing scrap to fall worldwide. Because of

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the cutbacks in Europe and the declining price for primary nickel, U.S. exports of stainless steel scrap dropped 18% between 1995 and 1996. The bulk of the scrap went to meltshops in the Republic of Korea (26% of the total tonnage for 1996), Spain (21%), Canada (18%), and Taiwan (14%). The exported scrap contained an estimated 22,754 tons of nickel, down from 27,613 tons in 1995. These last figures are based on the assumption that stainless scrap has been averaging 7.5% nickel since 1989, when the changeover to the Harmonized Tariff System took effect. In recent years, U.S. exporters have had to compete against growing sales of Russian scrap to Western Europe and Japan.

At the beginning of each calendar year, the Bureau of the Census makes numerous changes to the U.S. foreign trade classification system in order to keep the system current in an evolving global marketplace. These changes, which usually affect both the Harmonized Tariff Schedule of the United States (Imports) and Schedule B (Exports), follow guidelines issued by the World Customs Organization in Brussels and the U.S. International Trade Commission in Washington, DC. In 1996, several changes were made to Chapter 75 of the tariff schedule: "Nickel and Articles Thereof." All of these changes affected HTSUSA heading 7508: "Other Articles of Nickel." A new subheading—7508.10.0000—was created for "Cloth, grill, and netting of nickel wire." The existing category for "Stranded wire" (previously 7508.00.1000) was assigned a new heading of 7508.90.1000.

World Review

Australia.—WMC Limited continued to set new production records at its operations in Western Australia. In fiscal year ending June 30, 1997, the company produced 104,667 tons of nickel in concentrate—breaking all previous records for the fifth consecutive year (WMC Limited, 1997). The new Mount Keith Mine northwest of Leinster was in its second year of operation and accounted for 35% of the total output, making it one of the larger metal mines in Australia. The Mount Keith concentrator treated 9.95 million tons of ore grading 0.60% nickel during the 12-month period, recovering 36,700 tons of nickel contained in concentrate. The concentrate was being dried at Leinster and then shipped either to WMC's smelter at Kalgoorlie or the Harjavalta smelter of Outokumpu Oy in Finland.

During the same 12-month period, WMC's other two mining operations—Kambalda and Leinster—produced 30,368 tons and 37,599 tons of nickel in concentrate, respectively. The recently expanded smelter at Kalgoorlie produced 72,939 tons of nickel in matte, but was still handicapped by air quality control restrictions. A new A$168 million acid recovery plant commissioned in July 1996 should reduce future sulfur dioxide emissions by 90%, permitting the smelter to operate at full capacity. WMC's nickel refinery at Kwinana produced a record 47,577 tons of metal in FY 1996-97, up 2% from 1995-96.

The Forrestania Mine near Varley, Western Australia, produced 9,500 tons of nickel in concentrates in calendar year 1996, compared with 7,600 tons in 1995. The mining operation excavated 700,000 tons of ore averaging 1.8% nickel. The mine has 500,000 tons of proven reserves and an additional 600,000 tons of probable reserves (Outokumpu Oy, 1997). The open pit mine has been in operation since 1992 and is owned by Outokumpu Mining Australia Pty. Ltd., a wholly owned subsidiary of Outokumpu Base Metals Oy and its parent, Outokumpu Oy of Finland. Outokumpu Mining Australia has three other projects under development in Western Australia: Silver Swan, Cygnet, and Black Swan. All three are 50-50 joint ventures with Mining Project Investors Pty. Ltd. (MPI) of Australia. Because Outokumpu Oy also owns 34% of MPI, it effectively has a 67% equity in each of the three projects. Mining was scheduled to begin at the Silver Swan in mid-1997 and is expected to continue for at least 5 years. The new underground mine has 640,000 tons of probable reserves with an exceptionally high grade of 9.5% nickel (Outokumpu Oy, 1997). The Silver Swan is expected to produce 12,000 tons of nickel in concentrates annually, all of which will go to the Harjavalta smelter in Finland. Outokumpu also has a 35% interest in the Honeymoon Well deposit south of Wiluna, near Lake Way and Mount Keith. The other 65% is held by the giant Rio Tinto Limited Group.

Several other mining projects were in various stages of development in Western Australia. In May 1996, Anaconda Nickel Limited completed its feasibility study of the Murrin Murrin laterite deposit, 55 kilometers east of Leonora, and decided to go ahead with the project. In October, Glencore International AG of Switzerland increased its stake in Anaconda from 14.53% to 19.99%—just below Australia's 20% threshold for regulating investments. A few weeks later, Glencore agreed to pay $220 million for a 40% interest in the Murrin Murrin project, assuring initial financing of the mine. According to Anaconda officials, infill drilling now indicates that the deposit has at least 128 million tons of ore grading 1.01% nickel and 0.064% cobalt (Anaconda Nickel Limited, 1997).

A pressure acid-leaching plant was to be built on-site to extract the nickel and cobalt directly from the lateritic ore. The extraction process would be similar to the one used at the Moa plant in Cuba, producing a mixed sulfide precipitate containing about 55% nickel and 4% cobalt. The nickel-cobalt precipitate would then be redissolved, allowing the two metal ions to be separated from one another by solvent extraction. After separation, the nickel—now dissolved in an ammoniacal solution—would be fed into an autoclave and reduced to a metal powder in a hydrogen atmosphere.

Construction of the open pit mine and pressure acid leach plant was expected to cost A$900 million, or about US$655 million. Fluor Daniel Australia Ltd. was responsible for the overall design and engineering. Sherritt International was supplying the technology for hydrometallurgically extracting the nickel and cobalt. Development was to be carried out in two stages, with commissioning scheduled for the fourth quarter of 1998. At the end of the first stage, the proposed plant would be able to process about 3.75 million tons of ore per year, producing 31,500 tons per year of nickel in briquets, 13,500 tons per year of nickel in concentrate, and 3,500 tons per year of

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cobalt. The second stage would raise the capacity of the operation to 75,000 tons of nickel and 4,500 tons of cobalt. As of June 30, 1997, Stage 1 of the project was 24% complete.

The Goldfields natural gas pipeline was completed in late 1996. The 1,380-kilometer-long pipeline carries gas from offshore fields in the Canarvon Basin on the North West Shelf to iron ore operations in the Pilbara and then on to nickel and gold operations as far south as Kalgoorlie. Gas began arriving at Mount Keith and Leinster in August and at Kambalda and Kalgoorlie in September. The cheaper energy provided by the pipeline was expected to spur development of Bulong, Cawse, and several other nickel laterite deposits along its route. Construction of the pipeline was financed by the Goldfields Gas Transmission Joint Venture. The venture is jointly owned by WMC (62.7% equity), BHP Minerals Pty. Ltd. (11.8%), and Normandy Poseidon Ltd. (25.5%). Boral Energy, one of the gas suppliers using the pipeline, has agreed to supply gas on a daily basis to Murrin Murrin. Boral Energy will build, own and operate an 80-kilometer spur line from Leonora to Anaconda's new extraction and refining facilities.

Canada.—Initial steps taken to develop the Voisey's Bay deposit have already begun to affect the future of both Labrador and Newfoundland. The deposit is the most important base metal discovery in Canada in more than 30 years. In 1996, new exploration data revealed that the nickel-copper-cobalt mineralization was more extensive than originally thought. The principal ore minerals are pentlandite, chalcopyrite, and pyrrhotite. As more and more drill holes intersected ore in the massive sulfide deposit, it became apparent that Voisey's Bay may prove to be one of the lower-cost sources of nickel in the world. The remote deposit is 35 kilometers southwest of the town of Nain and only 10 kilometers from a natural deep-water harbor that opens into the Labrador Sea. The harbor, at Edward's Cove on Anaktalak Bay, was to be the site of the concentrate shipping docks, a fuel storage facility, and one of two base camps.

The Voisey's Bay deposit was discovered in 1993 by two partners in a small exploration company while prospecting for diamonds as well as sulfides. In late 1994, geophysical surveying delineated a strongly conductive anomaly in the vicinity of the original discovery site—a large iron-stained hill of gossan (i.e., the oxidized capping of a ferruginous sulfide deposit). Four holes were drilled into the anomaly, one of which intercepted 33 meters of massive sulfides. Since then, airborne geophysical surveys have been conducted over 1,800 square kilometers of claims staked in the vicinity of the discovery site. Followup geophysical surveying revealed that the anomaly associated with the site widens to the east, where it takes on an ovoid shape. In January 1995, crews began drilling the ovoid feature and again intercepted massive sulfide. The mineralization at this point lies immediately below the overburden, permitting open pit mining. The second drill hole (VB-95-07) to test the feature penetrated 104 meters of massive sulfide grading 3.93% nickel, 2.84% copper, and 0.14% cobalt.

More than 340 holes have been drilled on the property since 1994 and several high-priority targets still have not been evaluated. By mid-1996, three separate zones had been identified: the Ovoid, the Eastern Deeps, and the Western Extension (Voisey's Bay Nickel Company Limited, 1996b). The three zones are associated with the Reid Brook Intrusion and, in plan view, are aligned over a distance of almost 6 kilometers. The Ovoid is in the middle. The Ovoid zone has an estimated 31.7 million tons of ore averaging 2.83% nickel, 1.68% copper, and 0.12% cobalt—all of which is amenable to open pit mining. The Ovoid ore body has a wine-glass shape in section and is roughly 450 meters in length. In plan view, it is 300 meters wide at its thickest point. Preliminary drilling of the Eastern Deeps zone along a 1-kilometer traverse identified an additional 50 million tons of resources at depth averaging 1.36% nickel, 0.67% copper, and 0.09% cobalt. Subsequent drilling results suggest that this second zone may actually contain over 100 million tons of resources. Limited drilling also delineated a zone of high grade mineralization in the Western Extension that contains some 20 million tons of resources, but much more work was needed before this third resource could be satisfactorily estimated (Inco Limited, 1997b).

In late 1996, drilling crews identified a fourth zone of mineralization, 2 kilometers west of the Ovoid. This fourth zone lies beneath, and is partly contiguous with the shallower zone of the Western Extension. The newly discovered zone is in the shape of a flattened cylinder that plunges to the east towards the Ovoid. The mineralization lies 250 to 600 meters below the surface, extending over a strike length of at least 500 meters. Drill hole assays from the core of the fourth zone range from 1.2% to 2.8% nickel, indicating that the mineralization is richer than the disseminated sulfide resource found in the Eastern Deeps (Inco Limited, 1997b).

Falconbridge Limited and Inco quickly realized the significance of the Voisey's Bay discovery. Each took steps to acquire the deposit from the original owner, Diamond Fields Resources Inc. The Voisey's Bay Nickel Company Limited, a subsidiary of Diamond Fields at the time, held exploration and development rights to the deposit along with rights to 2,000 square kilometers of other land in Labrador. In June 1995, Inco acquired 7% of Diamond Fields' common stock for $111 million. At the same time, Inco also acquired a 25% interest in the deposit itself as part of a related but separate transaction with Diamond Fields. This second transaction cost Inco $387 million in preferred stock and $18 million in cash. Inco also acquired 2 million common shares of Diamond Fields from three private shareholders. The three shareholders received a total of 1.4 million shares of Inco common stock and $68 million in cash. The various agreements gave Inco roughly a 30% interest in the immense deposit. Inco was to be responsible for marketing all of the nickel and cobalt under a long-term agreement.

In late 1995, Falconbridge approached Diamond Fields and offered to acquire the 75% of Voisey's Bay Nickel not held by Inco. Under the terms of the proposal, Diamond Fields would have merged with Falconbridge. Diamond Fields shareholders were to have received Falconbridge stock and corporate notes plus a limited amount of cash in exchange for their common

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share holdings. However, under the terms of the June 1995 agreement with Diamond Fields, Inco had the right to submit a counterproposal. Inco's management immediately began evaluating a variety of possible responses and postponed commenting on the matter for 3 months. On February 9, 1996, the board of directors of Diamond Fields unanimously approved Falconbridge's merger proposal, putting pressure on Inco to make a decision. Falconbridge's offer indicated that discovery of the Voisey's Bay deposit had transformed Diamond Fields into a company worth at least $4 billion.

Following brief, intense negotiations, Inco made a counteroffer directly to Diamond Fields' board of directors. The counteroffer was made public on March 26, 1996. Inco would acquire all of the common shares of Diamond Fields that were not already owned by Inco. In exchange, Diamond Fields shareholders would receive cash, Inco common shares, and two types of Inco preferred stock. At the time, financial experts estimated Inco's counteroffer to be worth about $3.5 billion. On April 3, Diamond Fields' board of directors provisionally accepted Inco's counteroffer and submitted it to their shareholders for approval (Heinzl, 1996). At that point, Falconbridge withdrew from the bidding. Both the shareholders of Inco and Diamonds Fields approved Inco's proposal.

On August 21, Inco completed its acquisition of Diamond Fields, giving it control of the Voisey's Bay deposit. The settlement formalized the provisional agreement reached with Diamond Fields' management on April 3. Inco's accountants valued the stock exchange and cash settlement at $3.093 billion (Inco Limited, 1997a). Two days after settlement, Inco set up a special executive team to oversee development of the Voisey's Bay deposit and the construction of related processing facilities in the Province of Newfoundland and Labrador. The seven-member team was based in St. John's, Newfoundland. The Labrador operation remained under control of Voisey's Bay Nickel, which was converted into a wholly owned subsidiary of Inco. Under the terms of the settlement, Inco can sell—without restrictions—up to 24% of Voisey's Bay Nickel if need be. Inco also took over control of Diamond Fields' exploration properties in Greenland and Norway. In September, Inco filed for environmental permitting of the proposed mine and mill complex at Voisey's Bay. If everything proceeds according to the current schedule, production of concentrate could begin in late 2000.

On November 29, 1996, Voisey's Bay Nickel announced that it was planning to build a major smelting and refining complex at Argentia on the island of Newfoundland (Brockelbank, 1996a; Voisey's Bay Nickel Company Limited, 1996a). The complex would process all of the nickel-cobalt concentrate produced at Voisey's Bay. (*See Current Research and Technology.*) Argentia was chosen over a number of other sites on the island and in Labrador. The proposed site is on the north side of a former U.S. naval base, about 130 kilometers west of St. John's. The Argentia complex would cover about 2 square kilometers (500 acres) and could be in full production as early as 2001. When fully operational, the complex would be able to process 816,000 tons per year of sulfide concentrate and produce 122,000 tons per year of refined nickel and 3,000 tons of cobalt, making it the largest nickel operation outside of Russia. It also would be somewhat larger than Inco's operation at Sudbury, Ontario, which is rated at about 100,000 tons per year of nickel in smelter products. About 16,000 tons per year of copper would be produced at Argentia as a byproduct from the nickel-cobalt concentrate.

The mill at Voisey's Bay also would produce a separate predominately chalcopyrite (i.e., copper-rich) concentrate. This second sulfide concentrate, representing about 80% of the copper in the ore, would be processed elsewhere for economic reasons. A viable, dedicated copper smelting and refining operation would require considerable more copper concentrate than that projected from Voisey's Bay. The mill would produce about 75,000 tons per year of copper in chalcopyrite concentrate.

Argentia is on tidewater and close to some major North Atlantic shipping lanes, permitting Voisey's Bay Nickel to economically supplement its feedstocks with nickel concentrates purchased on the world market. The site also is relatively close to inferred resources of nickel sulfides being evaluated in the Lac Manitou, Sept-Îles, and Gaspé regions of southeastern Quebec as well as in parts of Maine. All four regions could conceivably supply additional nickel concentrate for the smelter.

The Voisey's Bay discovery has spurred nickel exploration throughout Eastern Canada and heightened expections of a number of small exploration companies. In August 1996, a team of geologists employed by the Provincial Government of Quebec encountered two gossans while mapping part of the Lac Manitou-Lac Nipisso area. The discovery was made near Lac Volant, a smaller lake east of Lac Nipisso. Lac Volant is about 60 kilometers northeast of the iron ore port of Sept-Îles and lies within the Grenville structural province of the Precambrian Canadian Shield. As soon as officials of the Quebec Government learned of the find, they temporarily withdrew 800 square kilometers of land surrounding the gossans from staking. Government geologists have since staked more than 130 claims for the Crown within the withdrawn parcel. St. Geneviève Resources Ltd. and Virginia Gold Mines Inc., already exploring in the area, quickly staked more than 1,000 claims around the perimeter of the withdrawn area. Surface samples from a number of these claims showed enrichment of copper, nickel, and cobalt.

On October 9, the Quebec Government lifted its ban, triggering a staking rush along the entire North Shore of the St. Lawrence estuary. Other companies currently exploring the North Shore include Azimut Exploration Inc., Falconbridge Limited, Fancamp Resources Limited, GeoNova Explorations Inc., Inco Limited., Kennecott Canada Inc., and Vior Mining Exploration Co. Inc. (Brockelbank, 1996b). The drilling results to date have been disappointing. If the Lac Manitou area should turn out to be a significant resource of nickel, sulfide concentrates could be shipped relatively easily across the Gulf of St. Lawrence to Argentia. Lac Volant is only about 15 kilometers from the Quebec North Shore and Labrador Railway, which operates between Sept-Îles and the iron mines near

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Labrador City.

Falconbridge continued moving forward on its Raglan Project in the Nunavik territory of northern Quebec. The development of the mine and concentrator at Katinniq was slightly ahead of schedule. Most of the buildings were in place and all of the road and site preparation has been completed. About 450 people were working at the site. The mill modules were being constructed in Quebec City and were to be transported to Katinniq in mid-1997. Mining was to begin in December 1997, with the first shipment of concentrate due to leave Deception Bay in early 1998 (Falconbridge Limited, 1997). The concentrate would be shipped by sea to Quebec City and then railed to the company's smelter at Sudbury. Falconbridge had been planning to produce 20,000 tons per year of nickel in concentrate over the first 15 years of operation. However, recent drilling has identified three new zones of mineralization, adding 1.3 million tons of resources to Raglan's ore reserves. According to Falconbridge officials, the Raglan deposit now has 20.6 million tons of proven or possible reserves (Falconbridge Limited, 1997). Of the 20.6 million tons, 14.4 million are proven or probable, averaging 3.17% nickel and 0.88% copper. The additional reserves may permit Falconbridge to increase Raglan's capacity in the future to 30,000 tons per year of nickel.

In the Sudbury Basin of Ontario, Falconbridge was in the process of bringing its previously idled Lockerby Mine into full production. In 1996, the mine produced 92,000 tons of ore averaging 2.27% nickel and 1.19% copper—containing some 2,100 tons of nickel and 1,100 tons of copper. By 1998, production should reach 8,000 tons of contained nickel and 3,500 tons of contained copper. Falconbridge had four other nickel-copper mines operating along the rim of the Basin—the largest being the Onaping/Craig complex. Underground exploration drilling at Onaping/Craig since 1995 has identified significant additional sulfide mineralization. In 1996, Falconbridge's five mines in the basin extracted a total of 2.81 million tons of ore averaging 1.77% nickel and 1.93% copper. The company's smelter at Falconbridge recovered 45,709 tons of nickel and 17,552 tons of copper in matte made from the mined ores and custom feed.

Inco's new McCreedy East Mine at Sudbury came on-line in 1996 and should be in full production by 1999. McCreedy East is one of the company's lower-cost mines in Canada and, when fully operational, will have an annual production capacity of 11,000 tons of contained nickel and 28,000 tons of contained copper. At the end of 1996, Inco's Victor Deep exploration shaft on the northeastern edge of the basin was close to its planned depth of 1,460 meters. Underground exploration drilling outward from levels near the bottom of the shaft was to begin in 1997.

In Manitoba, Inco continued to deepen its Birchtree Mine and fully develop its 1-D ore body. At yearend 1996, Inco's Canadian mines had 364 million tons of ore reserves. The reserves contained 5.66 million tons of nickel and 3.72 million tons of copper, which equated to an average grade of 1.56% nickel and 1.02% copper (Inco Limited, 1997a). The total does not include additional resources associated with the Voisey's Bay deposit in Labrador, the Victor Deep deposit near Sudbury, and recent discoveries in the Pipe area of Manitoba.

Colombia.—In June 1996, the Government of Colombia announced that it would sell its 47.69% interest in Cerro Matoso S.A. (CMSA). CMSA operates an open pit laterite mine and smelter near Montelibano in the Department of Cordoba. The Government had been planning to privatize CMSA for some time and finally decided in September to sell almost of its holdings to its partner, Gencor Limited of South Africa. The sale, which was completed in February 1997, increased Gencor's equity in the ferronickel producer from 52.31% to 98.88%. The remaining 1.12% of the shares was held by CMSA employees, together with employee unions. Gencor paid the Government of Colombia 178 billion pesoes, or about $166 million, for its holdings (Billiton Plc., 1997). CMSA is currently paying the Government a royalty of 8% of the gross value of the ferronickel extracted less processing costs. The royalty was to rise to 12% in the year 2007. As part of the sales agreement, CMSA gained rights to exploit the concession until 2026 and has an option to extend these rights to 2041.

In 1996, the Cerro Matoso smelter produced 22,934 tons of nickel contained in ferronickel bars and granules, down 7% from the record 24,565 tons set in 1995. The nickel content of the ferronickel ranged from 39% to 43%. The company exported 23,482 tons on a contained basis in 1996, 94% of which went to Europe. The remaining 6% was shipped to the United States. Electricity accounted for approximately 28% of the company's cash production costs in 1996. In April, CMSA entered into a 5-year agreement with Corporación Eléctrica de la Costa Atlántica, the state-owned electricity supplier. As of June 30, 1996, CMSA had 31.3 million tons of proved ore reserves averaging 2.5% nickel and 14.1 million tons of probable reserves averaging 2.2% nickel (Billiton Plc., 1997).

Côte d'Ivoire.—Falconbridge Limited has been evaluating several laterite deposits northeast of Mount Nimba where the borders of Côte d'Ivoire, Guinea, and Liberia intersect. The project is part of a joint venture with Trillion Resources Ltd. of Kanata, Ontario, and the Société d'État pour le Développement Minier de la Côte d'Ivoire. To date, much of the work has focused on pyroxenites in the highlands region between Biankouma and Touba, northwest of Man. Resources have been identified at three locations. At the end of 1995, the Foungouesso-Moyango area, 24 kilometers north of Biankouma, had 39.5 million tons of material, averaging 2.00% nickel, while the Viala-Yamatoulo-Touba area had 18.7 million tons averaging 1.77% nickel. The Sipilou North area had 54.0 million tons grading 1.80% nickel and 0.10% cobalt (Falconbridge Limited, 1996). Additional material was identified during the 1996 drilling program, increasing total known resources to 226.3 million tons with an average grade of 1.50% nickel and 0.10% cobalt (Falconbridge Limited, 1997).

Falconbridge launched the third phase of its drilling program in October 1996 and, at yearend, had a hydrometallurgical scoping/pre-feasibility study in progress. A miniscale pilot plant was being set up to process bulk samples. Earlier

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metallurgical tests had indicated that ferronickel could be made from the Biankouma-Touba laterites using the Falcondo process presently employed in the Dominican Republic. However, hydrometallurgical extraction is apparently proving to be more suitable and cost effective than pyrometallurgical extraction in this particular situation. Satisfactory completion of the exploration program should earn Falconbridge a 60% interest in the Biankouma-Touba project (Trillion Resources Ltd., 1997). In December, Falconbridge signed a memorandum of understanding with the Government of the Côte d'Ivoire that outlined a schedule for further project work and specified key downstream decision points if development proves economically feasible (Falconbridge Limited, 1997).

Cuba.—Metals Enterprise continued to modernize the Moa mining and mineral processing facility in Holguín Province. The vertically integrated enterprise is a 50-50 joint venture between General Nickel of Ciudad Habana and Sherritt International Corp. of Toronto, Canada. Cuba's other nickel processing plants—Nicaro and Punta Gorda—are not part of the joint venture. In 1996, the Moa facility produced 26,034 tons of nickel and cobalt contained in mixed sulfides, more than double the 12,549 tons reported for 1994 when the joint venture was formed (Sherritt International Corporation, 1997). The sulfide precipitate was being shipped from Moa Bay via Halifax, Nova Scotia, to the joint venture's nickel-cobalt refinery at Fort Saskatchewan, Alberta. In 1996, the Fort Saskatchewan refinery produced 25,300 tons of nickel in metal powder and briquets together with 2,100 tons of refined cobalt. This was the highest output in the refinery's 43-year history.

Metals Enterprise will spend approximately $165 million rehabilitating and upgrading the Moa facilities over the next 3 years. By 1999, the Moa facility should be able to produce 27,000 tons of contained nickel plus cobalt per year. A pressurized leach process is used to extract the two metals from the goethite ore. The process is relatively efficient, recovering more than 90% of the nickel, but consumes large amounts of sulfuric acid. Almost one-third of the modernization money was being used to replace the three existing acid plants with a single modern unit capable of producing 1,500 tons of acid per day. One of the three plants was permanently closed in September 1995 because of high maintenance costs, but the other two have been refurbished in the interim. Overhaul of one plant was completed in 1996; the second, in early 1997. Supplemental acid was being purchased on the open market.

WMC and Commerical Caribbean Nickel S.A. were in the final stages of formalizing their joint venture to evaluate and, if feasible, develop the Pinares de Mayari West lateritic deposit. In January 1996, WMC signed a Heads of Agreement with the Cuban parastatal, but a number of details of the joint venture still had to be worked out. The Pinares deposit is located in Holguín Province and reportedly contains more than 200 million tons of ore exceeding 1% nickel and 0.1% cobalt (WMC Limited, 1997). The feasibility work will take several years to complete. WMC's legal advisors believe that the greenfield project falls outside the purview of "The Cuban Liberty and Democratic Solidarity Act" (i.e., the Helms-Burton Act).

Dominican Republic.—Falconbridge Dominicana, C. por A., (Falcondo) produced 30,376 tons of nickel in ferronickel, down slightly from the 30,886 tons reported for 1995. More than 90% of the ferronickel was in the form of ferrocones, a product resembling a large metallic gumdrop and weighing about 125 grams. The tonnage of lateritic ore delivered to the processing plant in 1996 was the second highest in the history of the Bonao Mine, but the average grade of the ore was only 1.32% nickel—the lowest on record (Falconbridge Dominicana, C. por A., 1997).

Over the last few years, the grade of the laterite mined at Bonao has gradually declined. To counter the dropoff in nickel content, Falcondo has begun developing an improved circuit for upgrading the laterite prior to reduction in the electric arc furance. The process, which grinds the ore more finely, is still at the pilot-plant stage but could increase annual production by 4,000 tons of nickel in ferronickel, while simultaneously lowering operating costs. If successful, the cutoff grade for the mine could be lowered from 1.2% nickel to 1.0%, increasing ore reserves by more than 60% and extending the life of the mine from 21 to 33 years (Falconbridge Limited, 1997).

European Union.—Finland.—In 1995, Outokumpu Base Metals Oy completed a major expansion of its Harjavalta smelter and refinery in Turku-Pori Province, Finland. The expansion raised the production capacity of the complex to 32,000 tons per year of nickel briquets and cathode and 160,000 tons per year of blister copper. In 1996, parts of the smelter and refinery were still in a startup mode and experiencing operational problems related to the expansion (Outokumpu Oy, 1997). Despite these problems, Harjavalta produced 29,300 tons of nickel and 150,300 tons of blister copper—a dramatic increase in comparison to 1995 when interruptions linked to the expansion caused output to drop to 18,400 tons of nickel and 88,300 tons of copper. Plans have already been drawn up to increase the annual production capacity of the smelter to 40,000 tons of nickel. In the fall of 1996, the LME registered Outokumpu's new nickel briquets, permitting them to move freely in the global marketplace.

Outokumpu Base Metals has only one nickel mine still operating in Finland—the Hitura Mine near Ainastalo. Because of declining ore reserves, the Vammala Mine was closed in January 1995. Since March 1995, the Harjavalta smelter has relied mainly on concentrates from WMC's new Mount Keith Mine and Outokumpu's own Forrestania Mine, both in Western Australia. In 1996, the Hitura Mine produced 3,100 tons of nickel in concentrate, the same tonnage as in 1995. According to company records, at the end of 1996, the Hitura Mine had 0.6 million tons of proven and probable reserves, averaging 0.7% nickel (Outokumpu Oy, 1997). The mine had an additional 6.1 million tons of measured, indicated, and inferred resources containing 0.8% to 0.9% nickel.

Indonesia.—P.T. International Nickel Indonesia (P.T. Inco) was in the midst of a major expansion of its mining and smelting complex on the island of Sulawesi. The $580 million expansion will take 3 more years to complete and raise the production capacity of the Soroako smelter from 45,000 tons per year of

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nickel in matte to 68,000 tons per year. P.T. Inco officials approved the expansion after the Government of Indonesia agreed to modify the company's Contract of Work and extend the contract to the year 2025. The original contract, signed in 1968, was due to expire in 2008. The new agreement was formally signed in Jakarta on January 15, 1996. The bulk of the additional production was expected to be consumed in Asia—reportedly the fastest growing market for nickel at the present time (Upton, 1997).

P.T. Inco produced 39,503 tons of nickel in matte in 1996, down 13% from the record high 45,463 tons of 1995. Production was interrupted on September 10 when one of the three electric arc furnaces at Soroako was damaged in an eruption. The furnace had to be rebuilt and did not come back on-line until December.

The matte, which averaged 78% nickel, was being shipped to Tokyo Nickel Company, Ltd. at Matsuzaka, Japan, for conversion into oxide sinter and utility nickel. The refining capacity of the Matsuzaka facility was being expanded by 50% to handle the additional output from Soroako. By late 1998, the Matsuzaka facility should be able to process 54,000 tons per year of nickel (Inco Limited, 1997a). Inco Limited, which owns 59% of P.T. Inco, also has a 51% interest in Tokyo Nickel.

On August 7, 1996, BHP Minerals Limited of Australia and P.T. Aneka Tambang of Indonesia formed a joint venture to evaluate lateritic nickel prospects on Gag Island, Irian Jaya (BHP Minerals Limited, 1996). Gag Island is about 130 kilometers southeast of Halmahera, Maluku and 150 kilometers northwest of Sorong at the northwestern tip of Irian Jaya. The nickel prospects on Gag Island have been known for some time and are currently held by Aneka Tambang. Aneka Tambang is a state-owned mining enterprise. The joint venture is hoping that advanced recovery technologies developed by BHP will make the Gag project economically feasible.

Gag Island is only 40 kilometers southeast of Gebe Island, Maluku, where Aneka Tambang has one of its two principal nickel mines. The other mine is near the company's ferronickel smelter at Pomalaa in southeastern Sulawesi. The Gebe Island Mine has been in operation since April 1979 and is currently shipping ore to Pomalaa, QNI Ltd.'s Yabulu Refinery in Queensland, Australia, and Japanese ferronickel producers. The open pit mine has 27 million tons of reserves averaging 2.2% nickel (BHP Minerals Limited, 1996).

BHP has a 75% interest in the Gag Island venture and has already submitted a Contract of Work to the Government of Indonesia. The initial feasibility study should be completed by January 1999. The Government of Indonesia is considering partially privatizing Aneka Tambang. A portion of the funds from the stock flotation would be used to expand the Pomalaa smelter. In 1996, the smelter produced 9,397 tons of nickel in ferronickel, down from 10,733 tons in 1995.

New Caledonia.—Société Métallurgique Le Nickel (SLN) operated three nickel mines on the island in 1996—Thio, Kouaoua, and Népoui-Kopéto. A fourth mine, Etoile du Nord (also known as Kaala-Gomen), was being operated by contractors. SLN mined 2.40 million tons of lateritic ore, slightly more than in 1995. The company also purchased 562,000 tons of ore from contractors working deposits owned by SLN. The bulk of the ore was screened at the individual mine sites and then shipped to the company's Doniambo metallurgical complex outside the capital of Nouméa (Eramet Group, 1997).

At Doniambo, the ores from the four mines were blended along with ores from a few independently operated mines, partially dried, calcined, and then smelted in one of three electric arc furnaces. The Doniambo smelter produces ferronickel containing 29% nickel and nickel matte that assays about 75% nickel. The matte is sent to the Sandouville-Le Havre refinery in northern France for conversion into cathode. The Sandouville refinery is owned by the Eramet Group, SLN's parent company. In 1996, the Doniambo smelter produced 42,173 tons of nickel in ferronickel and 11,239 tons of nickel in matte. The combined output of 53,412 tons was an all-time high for Doniambo, edging out 1995's record breaking 52,343 tons.

SLN accounted for 42% of New Caledonian mine production in 1996. The other 58% of mine production was divided between Société Minière du Sud Pacifique (SMSP), J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta, and several other independent mining companies. The overseas territory exported 69,358 tons of nickel in ore. The 69,358 tons of nickel included 34,795 tons in garnerite shipped to Japan; 15,248 tons in garnerite shipped to the United States; and 19,315 tons in limonitic laterites shipped to Australia.

In 1996, SMSP and Falconbridge formed a partnership with the intention of building a ferronickel plant in the North Province. The plant would have an annnal capacity of 55,000 tons of nickel in ferronickel and use local lateritic ores as feedstock (du Luart, 1997; Falconbridge Limited, 1997). The two companies have already prepared a scoping study and presented it to the governments of France and the territory. The ferronickel project was being supported by the Kanak Socialist National Liberation Front, a proindependence movement, which is especially strong in that part of the island (Buchan, 1997b). The Kanak Front has been told that the mining and smelting complex would employ 700 islanders and lead to the indirect employment of an additional 2,000. However, to be economically viable, the project requires a minimum of 25 years of ore reserves. These reserves exist, but many of the better deposits near the proposed plant site are already controlled by SLN, the principal mine operator on the island. There are three key deposits in the vicinity of the proposed plant: Tiébaghi, Poum, and Art. Together they have an estimated 1.6 million tons of nickel in garnierite reserves averaging 2.5% nickel (Eramet Group, 1997).

Eramet was being pressured to surrender key mining reserves in the Northern Province considered vital to the future viability of SLN (Eramet Group, 1997; Buchan, 1997a). Initially, SLN was asked to cede its new Tiébaghi Mine being developed at the northwestern tip of the island. Mining at Tiébaghi was scheduled to start in the second half of 1997. Eramet countered with a proposal calling for SMSP to cut back on its ore exports and, instead, use part of its mine production as

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feed for the proposed plant. SLN and the island's other mine operators would make up any shortages in feedstocks. Supported by the Government of France, SMSP then proposed to swap its Poum Mine for SLN's Koniambo deposit. The Koniambo deposit is roughly midway between Kaala-Gomen and Népoui-Kopéto and has much larger reserves than Poum. On December 17, Eramet's board of directors agreed in principle to the swap if adequate financial compensation was made to SLN. Negotiations stalled shortly afterwards. At yearend, the Government of France was considering buying or, as a last resort, expropriating the Koniambo deposit and turning it over to SMSP and Falconbridge. Eramet had not planned to mine the deposit until the year 2010.

The Government of France is the largest shareholder in Eramet, with an interest of 55%. The minority shareholders, which include several mutual funds and pension funds based in the United States and the United Kingdom, were strongly opposed to any type of expropriation. The Government was also considering paying Eramet some $300 million for the loss of Koniambo. If the concessions issue can be settled, construction of the SMSP-Falconbridge plant could begin as early as 1999, with production commencing in the year 2003 and continuing thru 2028.

The Kanak Front, the local trade unions, and the Government of France all would prefer to have more ore processed on the island and less exported. At yearend, the trade unions were threatening to block ore shipments in support of the proposed ferronickel plant. The citizens of New Caledonia are to vote on self-determination in a referendum sometime in 1998.

In July 1995, Inco initiated a feasibility study of its Goro holdings at the southeastern tip of the island. Drilling to date has delineated a resource of 150 million tons of lateritic material grading 1.6% nickel and 0.16% cobalt (Inco Limited, 1997e). The feasibility study was being sponsored by Goro Nickel S.A., a joint venture between Inco [85% interest] and France's Bureau de Recherches Géologiques et Minières (BRGM) [15%]. The nickel and cobalt would be recovered using a pressure acid leaching process combined with solvent extraction. The feasibility study was scheduled to be completed in late 1997.

Norway.—Falconbridge Nikkelverk A/S produced 61,584 tons of refined nickel, up 16% from 53,238 tons in 1995 (Falconbridge Limited, 1997). The jump was made possible by increased shipments of matte from both Falconbridge's smelter at Sudbury and BCL Ltd.'s smelter at Selebi Phikwe in Botswana. The Nikkelverk refinery at Kristiansand was capable of producing 69,000 tons per year, but suffered from a shortage of matte in 1995. The refinery, which was just upgraded in 1994, was being expanded again—this time to accommodate the matte scheduled to be made from Raglan's concentrates. When the expansion is completed in early 1998, the Nikkelverk complex will have an annual capacity of 85,000 tons of refined nickel metal and 3,700 tons of refined cobalt.

In December 1995, Outokumpu Base Metals Oy acquired a 70% interest in Nikkel og Olivin A/S. The remaining 30% was held by Nordlandsbanken AS, a Norwegian Bank. Nikkel og Olivin mines nickel sulfides at Ballangen, about 30 kilometers southwest of the iron ore port of Narvik in Nordland. In 1996, the entire annual output of the underground mine—some 4,000 tons of nickel in concentrate—went to the Harjavalta smelter in Finland.

Russia.—The Russian Federation produced 190,000 tons of nickel, about 5% less than in 1995. RAO Norilsk Nickel was by far the largest producer, accounting for 177,185 tons of nickel metal, along with 340,000 tons of copper metal, and 3,151 tons of cobalt in metal, oxide, or sulfate (Platt's Metals Week, 1997). Nickel production was down 2% from 1995, when the company's output was 180,100 tons. The decrease came at a time when the company was in a difficult financial situation, experiencing cash flow problems, and undergoing a change in management. The cash flow problems made it difficult for the company to meet its payroll and purchase essential supplies.

Norilsk Nickel was behind in its tax payments and, like several other companies with Arctic operations, was heavily in debt to its natural gas suppliers. The company's largest operation—the Norilsk Nickel Mining and Metallurgical Combine on the Taimyr Peninsula—was having difficulty maintaining production because of cutbacks in deliveries of natural gas. The combine's sole supplier, NorilskGazProm, was threatening to reduce deliveries by 25% if Norilsk did not pay $173 million owed the utility. NorilskGazProm has a monopoly on natural gas in the Taimyr region, but has been rapidly depleting its reserves, forcing the utility to raise prices. The metallurgical combine is the utility's biggest customer. Development of the Peliatkinskoe gas field would have helped alleviate the depletion problem, but NorilskGazProm lacked the massive financial resources required for such a project. Norilsk Nickel also was struggling with rising transportation costs. The company owed significant sums of money to the Russian merchant fleet servicing the vital port of Dudinka.

Norilsk Nickel was partially privatized in April 1994 and has since undergone a major restructuring of its management. The Russian government still remains the principal shareholder in the joint stock company and has put Uneximbank in charge of its interests. In November 1995, Uneximbank acquired 51% of Norilsk Nickel's voting stock from the Government under a controversial loans-for-shares program. The Government gave the stock to Uneximbank as collateral in exchange for a $170 million loan. The stock transfer was later approved by the Duma—the Russian parliament—effectively giving Uneximbank a 38% interest in the company. Uneximbank is one of the largest commercial banks in Russia and is based in Moscow. At yearend 1996, Uneximbank was hoping to gain official ownership rights to the giant nickel producer at a special auction that would be closed to foreign investors. The Government still considers Norilsk Nickel to be a strategic state asset. The controversial auction was scheduled for the summer of 1997. Uneximbank also was prepared to finance part of the Peliatkinskoe gas project.

Norilsk Nickel was under pressure from both foreign and domestic environmental groups to drastically reduce sulfur

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dioxide emissions from its three smelters. Scandinavian environmentalists have blamed the Pechenga smelter, in particular, for much of the sulfur dioxide found in the air over Lapland. The company was actively seeking loans from the Russian government to modernize all three facilities and correct the pollution problem. In 1993, Russian officials awarded a contract to a Norwegian-Swedish engineering consortium to modernize the Pechenga smelter, but a number of details in the final contract were never resolved. The consortium was composed of Elkem Technology (Oslo), Kvaerner Engineering (Oslo), and Boliden Contech AB (Stockholm). The Norwegian and Russian Governments had agreed to loan Norilsk Nickel almost one-half of the $258 million required for the project. The Pechenga modernization project was in limbo at the end of 1996, after a key meeting scheduled for December 20 between Kvaerner and Norilsk Nickel was postponed.

Russia has three smaller producers, all in the Ural Mountains: RAO Ufaley Nickel, RAO Yuzural Nickel, and RAO Režsky Nickel. The Ural producers continued to be hampered by escalating prices for energy, especially coal, and a shortage of capital for modernization.

According to statistics compiled by the central government, Russia exported 166,300 tons of unwrought nickel (HTS No. 7502) in 1996. Of the 166,300 tons, 135,600 tons, or about 82%, went into LME warehouses in Rotterdam. Other signficant destinations were Germany (6%), Finland (5%), and the Republic of Korea (2%). Norilsk Nickel did not ship any matte to Falconbridge's Nikkelverk refinery in Norway in either 1995 or 1996.

In the last few years, Russia has become an important source of nickel-bearing stainless steel scrap. Most of the scrap was coming from obsolete military and industrial equipment. Several foreign stainless steel producers and scrap trading firms have set up collection operations in Russia and Ukraine.

Current Research and Technology

The Sumitomo Refining Process.—Sumitomo Metal Mining Co. Ltd. of Japan has agreed in principle to license its patented matte chlorine leach electrowinning (MCLE) process to Inco. Inco wants to use the hydrometallurgical process in its proposed nickel smelting and refining complex at Argentia, Newfoundland (Inco Limited, 1997c). Feed for the Argentia complex would come by sea from Inco's new mine being developed at Voisey's Bay, Labrador.

The nickel-copper-cobalt ore mined at Voisey's Bay would be milled on-site. The Voisey's Bay mill would have a differential froth flotation circuit and produce two concentrates—one of pentlandite and one of chalcopyrite. Only the pentlandite concentrate would go to Argentia. The current plan calls for the chalcopyrite concentrate to be toll smelted elsewhere. Production of concentrate was scheduled to begin in late 1999.

At Argentia, Inco would convert the pentlandite concentrate into a pebble-sized, granulated nickel sulfide matte, using proprietary flash smelting technology developed in-house (Voisey's Bay Nickel Company Limited, 1996c). The oxygen flash smelting produces a crude iron-nickel-copper matte that has to be processed further in a converter to remove the bulk of the iron. In the converter, oxygen is blown up through the molten matte, oxidizing the iron which then enters the overlying silicate slag layer. After separation of the iron, the nickel-rich matte left in the converter—the Bessemer matte—is ready to be refined and Sumitomo's process enters into the picture.

The Bessemer matte has three principal components: Ni_3S_2, nickel-copper alloy, and Cu_2S. The MCLE process would be used to leach the nickel, copper, and cobalt from the matte, leaving behind elemental sulfur in a solid phase while simultaneously separating the copper from the nickel and cobalt. The sulfur would be drawn off, melted, filtered, and then pumped back to the smelter's sulfuric acid plant where it would be burned to sulfur dioxide and added to the off-gas feed stream from the flash furnace.

The MCLE process utilizes the cupric-cuprous redox couple to separate the nickel from the copper. The first step in the process is to grind the granulated matte and feed it as a slurry into a two-stage counter-current chlorine leach circuit. The chlorine leach solution contains cupric ion which immediately reacts with the nickel-copper sulfides in the matte. The freshly dissolved copper accelerates the leach process. A series of rapid reduction-oxidation reactions occurs, causing the nickel to dissolve out of the matte and the copper to precipitate out of the leach as a relatively insoluble cuprous sulfide cement. The cobalt is recovered from the copper-free pregnant liquor by precipitation as cobaltic hydroxide. The nickel-rich, cobalt-free chloride solution can now be fed into an electrowinning cell. During electrowinning, some of the chloride ions are oxidized and form chlorine gas. The chlorine gas is removed and recycled back to the chlorine leach circuit. The nickel is recovered as nickel metal cathode.

The cuprous sulfide cement and any undissolved nickel sulfides are bled off and fed into the main chlorine leach tank where the chlorine gas from the electrowinning cells are used to reoxidize the cuprous ion. The bulk of the dissolved copper is removed and recovered in a separate electrowinning circuit.

Sumitomo has been using the MCLE process to produce high-quality nickel metal and cobalt at its Niihama refinery in Ehime Prefecture, Japan, since 1992 (Ishikawa, 1994). The process is carried out in a closed system, making it environmentally friendly. The first refined nickel would be available from Argentia in late 2000, with full production in 2001. When fully operational, the complex will be able to process 816,000 tons per year of sulfide concentrate and produce 122,000 tons per year of refined nickel.

Sumitomo and Inco have been cooperating on projects for more than a decade. P.T. Inco's Soroako operation in Indonesia supplies much of the matte used at Niihama. In 1988, Sumitomo purchased a 20% interest in P.T. Inco from Inco Limited for $100 million. Prior to the acquisition, P.T. Inco was owned 98% by Inco and 2% by a consortium of six Japanese companies that included Sumitomo. The current equity breakdown for P.T. Inco is: Inco, 58.7%; Sumitomo, 20.1%;

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public shareholders, 20.0%; and four other Japanese companies, 1.2%. The public shares are traded on the Indonesian stock exchanges.

Nickel-Based Batteries for Electric Vehicles.—On December 5, 1996, General Motors Corp. (GM) began leasing its EV1 at dealerships in Southern California and Arizona (Akre, 1996). The EV1 is a new production vehicle rather than a conventional model modified to run on batteries. The two-passenger automobile has a 137-horsepower three-phase AC induction motor powered by a 16.8 kilowatt-hour maintenance-free lead-acid battery pack. It has a range of about 145 kilometers (90 miles) on the open highway, but only 113 kilometers (70 miles) in city traffic.

In June 1994, GM entered into a joint venture with Ovonic Battery Co., Inc. to manufacture EV batteries utilizing proprietary nickel-metal hydride technology developed by Ovonic Battery. The joint venture, GM Ovonic L.L.C., has been purchasing both negative electrodes and battery packs from Ovonic Battery. GM has a 60% interest in the joint venture; Ovonic Battery, 40%. GM Ovonic was to begin limited production of nickel-metal hydride battery packs for the EV1 in late 1997 or early 1998. The new nickel-metal hydride batteries reportedly are interchangeable with the lead batteries currently being used in the EV1, but are considerably more expensive to manufacture (Wrigley, 1997). The new nickel-metal hydride batteries are expected to increase the range of the EV1 to at least 190 kilometers (120 miles).

Solectria Corp. of Wilmington, MA, has begun selling a four-door sedan powered by Ovonic nickel-metal hydride batteries. Preliminary testing by the California Air Resources Board indicates that the Solectria has a range of 275 kilometers (170 miles) at approximately 80 kilometers per hour (50 miles per hour). Several Solectria models already have been delivered to the National Highway Traffic Safety Administration for testing to ensure that they fully comply with Federal motor vehicle safety standards.

Honda Motor Co. Ltd. of Japan, which owns 6.5% of Ovonic Battery, and Hyundai Motor Co. Ltd. of the Republic of Korea also have agreed to use Ovonic nickel-metal hydride batteries in their EV test fleets. Honda was to begin leasing its four-passenger compact EV to fleet owners in the Los Angeles and Sacramento areas of California in the spring of 1997. The vehicle, called the EV Plus, is made in Japan and has a rated range of 160 to 200 kilometers (100 to 125 miles) per charge in city traffic. The 288-volt brushless DC motor is powered by 24 12-volt sealed nickel-metal hydride batteries.

Nissan Motor Co. Ltd. was to launch a limited leasing and sales program in Japan for its Prairie Joy EV in the spring of 1997. The Prairie Joy can carry four people and is intended initially for local government and fleet users. The 1,690-kilogram EV is powered by lithium-ion batteries, developed jointly by Nissan and the Sony Corp. Lithium-ion batteries have about 1.5 times the energy density (i.e., storage capacity) of equivalent nickel-metal hydride batteries.

The Furukawa Battery Co., Ltd.—an Ovonic licensee—and Tohoku Electric Power Co., Inc. of Japan have jointly developed a nickel-metal hydride battery that provides a 150-kilometer (93-mile) driving range per charge at a constant speed of 40 kilometers per hour (25 miles per hour). Prototype EV's powered by the 15-kilowatt-hour battery have attained a top speed of 110 kilometers per hour (68 miles per hour). Other Ovonic licensees include Energizer Power Systems (formerly Gates Energy Products and now part of the Eveready Battery Co., Inc.); Canon, Inc., Japan; Gold Peak Industries (Holdings), Ltd., Hong Kong; Hitachi Maxell, Ltd., Japan; Matsushita Battery Industrial Co., Ltd., Japan; Samsung Electronics Co., Ltd., Republic of Korea; and VARTA Batterie AG, Germany.

In France, PSA Peugeot Citroën and Renault began manufacturing nickel-cadmium powered EV's on a limited scale. Peugeot Citroën, an alliance of Automobiles Peugeot and Automobiles Citroën, is Europe's third largest manufacturer of conventional automobiles. Peugeot Citroën currently has three EV models in production: the Peugeot 106 Electrique, the Citroën AX Electrique, and the Tulip. To date, the alliance has produced more than 1,000 EV's. The Tulip is a small special two-seater EV designed to complement existing urban transit systems. The alliance is also producing a scooter powered by nickel-cadmium batteries, which can attain a speed of 45 kilometers per hour.

For more than 6 years, Peugeot Citroën has been field testing some 50 EV's at the Atlantic port of La Rochelle. A network of recharging stations was set up around La Rochelle as part of the experiment. Peugeot formally introduced its new 106 Electrique in 1995. The two-door hatchback has three battery packs of 6-volt nickel-cadmium monoblocks. The three packs (a total of 20 monoblocks in series) provide 120 volts to a direct current motor. The nickel-cadmium batteries were being serviced by the manufacturer, SAFT SA, which has a brand-new nickel-cadmium battery manufacturing facility in Bordeaux. The 106 Electrique has a driving range of 80 kilometers and can accelerate from zero to 50 kilometers per hour in 8.5 seconds (PSA Peugeot Citroën, 1997). The EV retails for $18,150.

In October 1996, British sponsors bought fourteen 106 Electrique's and were field testing them in the Midlands city of Coventry (Simonian, 1996). The handful of hatchbacks and vans were being used by the Coventry City Council, East Midlands Electricity, PowerGen, and the Royal Mail.

In 1994, Peugeot Citroën joined with Générale de Transport et d'Industrie (GTI) and Cegelec to form the LISELEC Group, a futuristic EV rental company. The group is currently testing ten 106 Electrique's in the Paris region and is planning to set up a fleet of EV's for self-service operation throughout the region. Each LISELEC customer would be issued a pass and an associated personal code that would permit him or her to pick up an EV at any one of a network of parking stations and return it to any station of his or her choice. GTI, which operates public transit systems in 87 French towns, is responsible for designing the overall system and managing the parking stations. Cegelec will provide the central control system and the on-line computerized reservation/invoicing equipment. The Tulip would be the first rental EV used in the LISELEC system and is specially designed for this purpose. The vehicle is equipped

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with an on-board computer that communicates with the central control station. The Tulip network has the potential to dramatically improve the flexibility and net earnings of most metropolitan transit systems, and could prove to be an important end use for nickel.

Nickel-Based Household, Office, and Industrial Batteries.—Nickel-cadmium, nickel-metal hydride, lithium-ion and improved lead-acid electrochemical systems are also strongly competing with one another for the household, office, and industrial rechargeable battery markets. Improvements are continually being made to each of the systems. Energy density, cycle life, charge retention, shelf life, and performance at extreme temperatures are all being enhanced. France, Germany, Japan, and the United States continue to be the principal manufacturers and users of small-sized nickel-cadmium and nickel-metal hydride batteries. China, the Republic of Korea, and Taiwan also have made tremendous strides in this area since 1990. Japanese companies, in particular, have taken a global approach, building manufacturing plants in Belgium, Indonesia, Mexico and several other countries.

A global system for recycling nickel-cadmium and nickel-metal hydride batteries is rapidly becoming a reality. France, Japan, and the United States all have nationally mandated programs. The U.S. collection and recycling program for small rechargeable batteries is in a period of rapid expansion (England, 1996). The program is administered by the Rechargeable Battery Recycling Corporation (RBRC), a nonprofit public service corporation. RBRC generates revenue for the program by licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. More than 175 companies are currently participating in the program. The Portable Rechargeable Battery Association is also a sponsor and has helped to enlist the participation of county and municipal governments, hospitals, and fire departments. Spent nickel-cadmium, nickel-metal hydride, lithium-ion, and small sealed lead batteries are all being collected under the program. The program is now operating in 19 States at more than 4,500 retail locations. Some 300 counties also have drop-off centers. New projections indicate that, by the year 2005, roughly 70% of the spent nickel-cadmium batteries being generated in the United States will be recycled. The current recycling rate is about 15%. An estimated 85% of industrial nickel-cadmium batteries are recycled. Inmetco was expecting receipts of spent nickel-cadmium batteries in 1997 to be 20% to 25% greater than those of 1996. If the new RBRC program grows as expected, Inmetco could be handling 10,000 tons of batteries by the year 2002. It also helps that Inmetco now has on-site facilities for recovering and refining the accompanying cadmium and can convert it into marketable granules. Closing the cadmium loop removed the last major technical impediment to effective recycling of household and industrial nickel-cadmium batteries and has lessened environmental concerns about the collection program.

A similar battery recycling program exists in Japan. There, the program is being promoted by the Japan Storage Battery Association (JSBA), which represents 11 battery manufacturers. In 1995, Japanese battery manufacturers sold or exported 867 million nickel-cadmium cells and 305 million nickel-metal hydride cells. Statistics collected by the JSBA indicate that 31% of the 338 million cells sold domestically went into cellular telephones and other communications equipment. Another 25% went into home appliances (VCRs, shavers, etc.). The third largest market was office equipment, which accounted for 16%. The collection system supervised by JSBA feeds spent batteries into four regional recycling plants: Japan Recycle Center (with a processing capacity of 3,000 tons per year of batteries), Kansai Catalyst Ltd. (500 tons per year), Mitsui Mining & Smelting Co. Ltd. (a zinc refiner receiving 750 tons per year), and Toho Zinc Co. Ltd. (an electrolytic zinc refiner receiving 1,700 tons per year). Retailers, waste collectors, product manufacturers, and more than 1,900 municipalities all participate in the program (Fujimoto and Mukunoki, 1997). According to the latest available statistics, in 1994, Japan recycled 1,787 tons of spent nickel-cadmium batteries and 3,109 tons of nickel-cadmium battery scrap. Essentially all of the nickel-cadmium scrap generated in Japan at the battery plants is being recycled. However, the tonnage of spent batteries sent to recyclers is expected to rise dramatically between 1997 and the year 2000 as a result of new regulations, improvements in the JSBA-supervised collection program, and growing battery sales.

Spent nickel-cadmium batteries are being reclaimed by at least six plants in the European Union (Metal Bulletin, 1996). The largest European recycler is Sté. Nouvelle d'Affinage des Métaux S.A.R.L. (SNAM), which has two plants in France—one at Viviez in the Massif Central region and another at St. Quentin-Fallavier near Lyon (Broad, 1997). Together, the two process about 5,400 tons of spent batteries annually. SNAM also has ties to the SAFT NIFE AB recycling operation at Oskarshamn, Sweden, which can process an additional 1,500 tons. Other European recyclers include Hydrometal SA (Belgium), Uniniquel SA (Spain), and TNO/Esdex/Leto (Netherlands).

Outlook

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. World consumption of stainless steel is expected to grow between 3% and 9% annually from 1997 to the year 2005. This growth rate should increase substantially at some point when the Russian economy inevitably turns around and a rejuvenated Russian industry begins consuming the large amounts of stainless sheet and plate required by a technologically advanced, market-oriented society.

Several forces are helping to sustain long-term growth in nickel consumption. First, faster transport, the explosive expansion of telecommunications systems, and the globalization of markets are forcing local communities to be more technologically astute. As a result, society as a whole is becoming increasingly dependent on products fabricated from sophisticated starting materials—many of which contain

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significant nickel. Second, a technologically advancing society is continually demanding new materials with improved resistance to corrosion and heat—again favoring nickel. Recent life cycle studies have shown that horrendous bills for repairing highway bridges and similar infrastructure could have been avoided by substituting more expensive, but corrosion-resistant, stainless for traditional carbon steel in the original design. Third, the cost of producing a ton of stainless steel has fallen because of technological advances and improved economies of scale, making stainless more price competitive. Fourth, the population of the world is growing, increasing demand for quality stainless kitchenware, food processing equipment, sinks, and plumbing parts.

Demand for austenitic stainless steel has resumed its upward growth in several member countries of the Organization for Economic Cooperation and Development (OECD) that were weakened by the global recession of 1991-93. Stainless production capacity is being expanded in some of the newly industrialized countries of East Asia that successfully weathered the recession. Since 1990, production of austenitic stainless steel has been increasing in the Republic of Korea and Taiwan by more than 10% per year. Since 1994, Brazil and South Africa have become significant producers of stainless steel.

Demand for superalloys is expected to grow despite projected cutbacks in the defense programs of the OECD and Russia. Restructuring of the North American and European aerospace industries has spread to some of their raw material suppliers. The warming of relations between Russia and the United States, together with the peaceful expansion of the European Union, is having a tremendous effect on the nickel market. Russia is now a major source of nickel for the United States. The large stocks of nickel metal held by the U.S. Department of Defense are rapidly being sold off and should be exhausted within 3 years. The decline in orders for aerospace-grade metals and alloys from a downsized United States and Canadian defense industry has forced several of the industry's suppliers to restructure and seek out new civilian markets. The acquisition of Teledyne by Allegheny Ludlum is expected to be just the first step in a restructuring of the entire North American superalloys and specialty steel sector. U.S. specialty steel producers have been feeling pressure from their European competitors for some time.

The second step will be the assimilation of Inco Alloys International (IAI) by Haynes International Inc., an Indiana-based company. On June 11, 1997, Inco Limited announced that it had agreed to sell IAI to Blackstone Capital Partners II Merchant Banking Fund L.P. for approximately $410 million, excluding fees and expenses (Inco Limited, 1997d). Inco's alloy manufacturing division is one of the world's leading developers and producers of wrought nickel-base alloys. IAI has been supplying superalloys to the aerospace industry for more than 40 years from its plant in Huntington, WV. The division also has operations in Hereford, England; Burnaugh, KY; Elkhart, IN; and Newton, NC.

IAI products are bought by a broad spectrum of industry and have a myriad of applications in addition to aircraft engine components. Other end products include chemical processing equipment, food handling equipment, turbines and related power generation machinery, flue-gas scrubbers, downhole tubing for oil and gas wells, petrochemical storage tanks, and piping systems of all types. Incoloy, Inconel, Monel, and Nimonic are well known trademarks for families of high-nickel alloys produced by IAI.

Blackstone, a merchant bank based in New York, owns approximately 80% of Haynes. Haynes produces Hastelloy X, Waspaloy, and a variety of other nickel-base high-performance alloys. Blackstone is planning to combine the operations of Haynes and IAI, creating one of the largest producers of superalloys in the world (Coplan, 1997; Sacco, 1997). The new company would face a number of competitors, including Allegheny Teledyne Inc., Cannon-Muskegon Corp., Carpenter Technology Corp., Howmet Corp., Special Metals Corp., and VDM Technologies Corp. Approval still must be obtained from regulatory authorities and antitrust examiners (Ryan's Notes, 1997). The sale was scheduled to close in the fall of 1997 and should give Inco an after-tax gain of about $85 million. Part of the money would be applied to the debt incurred in acquiring the Voisey's Bay nickel-copper-cobalt deposit.

A third step is the proposed certification of Russian-made aerospace alloys for use by U.S. aircraft manufacturers. Verkhnaya Salda Metallurgical Production Association (VSMPO), Russia's only supplier of titanium alloy, recently had its Ti-6Al-4V aircraft quality ingot approved by Boeing, the Wyman-Gordon Co., and the Shultz Steel Co. (Karasyov, 1995). VSMPO also produces nickel-based high temperature alloys. Norilsk Nickel has strong ties to several capable metallurgical institutes in Russia and could gain North American industry support for Russian nickel-base superalloys through the company's long-established marketing arm in Western Europe.

EV's have begun to emerge from assembly plants in Western Europe, the United States, and Japan. Around the world, automobile manufacturers, metal producers, electric utility managers, environmentalists, and regulatory officials are all watching to see how these first mass-produced EV's will be received by the general public. Five different battery chemistries are being used: nickel-cadmium, nickel-metal hydride, valve-regulated lead-acid (VRLA), lithium-ion, and zinc-air. The outcome could significantly increase nickel demand and possibly even change nickel production technology if one of the two nickel batteries wins out in the competition.

The market for nickel-based batteries is expected to grow at least 6% per year over the next 10 years even if American automobile manufacturers decide not to put either nickel-cadmium or nickel-metal hydride cells in their new electric vehicles. Nickel-cadmium and nickel-metal hydride batteries are strong contenders for the rapidly growing electric scooter/bicycle market and will still be used in rechargeable power tools, home appliances, and other household equipment because of cost constraints. Nickel-cadmium and nickel-metal hydride batteries continue to compete head-on with lithium-ion alternatives in the portable electronics sector. However, over the last 3 years, nickel-metal hydride and lithium-ion batteries

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have been gaining ground against nickel-cadmium for some electronic end uses. The bulk of the nickel-metal hydride batteries are currently being used in communications and office equipment. In 1993, nickel-metal hydride batteries were introduced to the general public in Japan for the first time. Since then, sales have mushroomed. In Japan, nickel-metal hydride batteries have already captured 49% of the office equipment market, 32% of the communications market, and 4% of the home appliances market (Fujimoto and Mukunoki, 1997). Nickel-cadmium batteries continue to dominate the emergency lighting market.

The development of the Voisey's Bay deposit is expected to have a major impact on the world nickel supply, sharply reducing concerns about future shortages of the metal. Recent drilling has delineated additional resources at depth in the immediate area of the discovery site, spurring nickel exploration throughout all of eastern Canada as well as in Greenland. The discovery of the Voisey's Bay deposit has forced economic geologists to change some of their concepts on the genesis of massive sulfide deposits. This, in turn, has caused exploration companies to rethink some of their long-range targeting strategies for other parts of the Northern Hemisphere.

Western nickel producers have largely adjusted to the massive Russian exports of cathode. Supplies of stainless scrap have tightened, and the nickel industry is again expanding mining and smelting capacity on a global basis. Considerable effort is being expended on developing hydrometallurgical techniques that will improve the recovery of nickel from laterites. One of the more promising technologies is a combination of pressure acid leaching and solvent extraction.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Mine production	6,670	2,460	--	1,560	1,330
Plant production	8,960	4,880	--	8,290	15,100
Secondary recovery from purchased scrap:					
From ferrous scrap	47,700	46,600	48,900	54,400	48,800
From nonferrous scrap	8,140	7,460	9,690	10,200 r/	10,400
Exports:					
Primary	8,560	7,180	7,420	9,750	13,100
Secondary	25,300	26,000	34,500	41,800	33,600
Imports for consumption:					
Ore	3,580	2,970	--	8,200	15,000
Primary	119,000	126,000	127,000	149,000	142,000
Secondary	9,510	6,710	6,070 r/	7,930	8,060
Consumption:					
Reported:					
Primary	101,000 r/	105,000 r/	108,000 r/	124,000	116,000
Secondary (purchased scrap) 2/	55,900	54,000	58,600	64,500 r/	59,200
Total	157,000 r/	159,000	166,000	189,000 r/	175,000
Apparent:					
Primary	119,000	122,000	133,000 r/	152,000 r/	149,000
Secondary (purchased scrap)	40,300	36,600	30,500 r/	29,500 r/	33,600
Total	159,000	158,000	164,000 r/	181,000 r/	183,000
Stocks, yearend:					
Government	33,800	31,600	26,800	19,800	15,900
Producers and traders	10,100	15,700	10,200	12,700 r/	11,200
Consumer:					
Primary	12,300	11,100	8,040 r/	8,130	8,690
Secondary	5,240	3,360	3,020 r/	4,150	4,210
Employment, yearend:					
Mine	10	2	1	17 r/	8
Smelter	250	33	22	253 r/	253
Port facility	23	5	3	25	23
Price, cash, London Metal Exchange:					
Per metric ton	$7,001	$5,293	$6,340	$8,228	$7,501
Per pound	$3.176	$2.401	$2.876	$3.732	$3.402
World: Mine production	1,010,000 r/	926,000 r/	929,000 r/	1,030,000 r/	1,080,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits, except prices; may not add to totals shown.

2/ More nearly represents amount consumed than does apparent secondary consumption; internal evaluation indicates that apparent secondary consumption is considerable understated.

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TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE
UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons of contained nickel)

	1995	1996
Kind of scrap:		
Aluminum-base 2/	3,280	3,250
Copper-base	2,720	3,120
Ferrous-base 3/	54,400	48,800
Nickel-base	4,170 r/	4,050
Total	64,500 r/	59,200
Form of recovery:		
Aluminum-base alloys 4/	3,280	3,250
Copper-base alloys	4,540 r/	4,910
Ferrous alloys	54,400	48,800
Nickel-base alloys	2,300 r/	2,160
Miscellaneous and unspecified	--	37
Total	64,500 r/	59,200

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Primarily used beverage cans and foundry borings and turnings.
3/ Primarily stainless and alloy steel scrap consumed at steel mills and foundries.
4/ Includes can scrap converted to ingot by toll smelters for sale on open market.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM 1/

(Metric tons of contained nickel)

Form	1995	1996
Primary:		
Metal	93,700 r/	86,300
Ferronickel	21,800 r/	22,900
Oxide and oxide sinter 2/	3,250	1,460
Chemicals	4,310	4,720
Other	1,440	804
Total primary	124,000	116,000
Secondary (scrap) 3/	64,500 r/	59,200
Grand total	189,000 r/	175,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes chemical-grade oxide.
3/ Based on gross weight of purchased scrap consumed and estimated average nickel content.

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TABLE 4
U.S. CONSUMPTION OF NICKEL IN 1996, BY USE 1/

(Metric tons of contained nickel)

Use	Metal	Ferro-nickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total 1996	Grand total 1995
Cast irons	175	W	(2/)	W	43	218	345	563	491 r/
Chemicals and chemical uses	1,100	--	W	4,220	--	5,310	--	5,310	5,210 r/
Electric, magnet, expansion alloys	W	--	--	--	--	W	W	W	W
Electroplating (sales to platers)	16,200	(2/)	W	44	W	16,200	W	16,200	15,600
Nickel-copper and copper-nickel alloys	3,250	W	W	--	W	3,250	4,050	7,300	8,510 r/
Other nickel and nickel alloys	17,800	W	W	--	W	17,800	1,930	19,700	21,800 r/
Steel:									
Stainless and heat resistant	24,100	21,800	426	--	70	46,400	47,600	94,000	103,000 r/
Alloys (excludes stainless)	5,390	W	W	--	W	5,390	851	6,240	9,570 r/
Superalloys	12,600	--	(2/)	W	W	12,600	W	12,600	14,100 r/
Other 3/	5,680	1,110	1,030	459	691	8,970	4,440	13,400	10,300 r/
Total reported	86,300	22,900	1,460	4,720	805	116,000	59,200	175,000	189,000 r/
Total all companies, apparent	XX	XX	XX	XX	XX	149,000	33,600	183,000	181,000 r/

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM 1/

(Metric tons of contained nickel)

Form	1995	1996
Primary:		
Metal	6,190 r/	6,150
Ferronickel	674	1,620
Oxide and oxide sinter	324	181
Chemicals	808	565
Other	129	177
Total primary	8,130	8,690
Secondary (scrap)	4,150	4,210
Grand total	12,300	12,900

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS 1/

(Metric tons of contained nickel unless otherwise specified)

Class	1995 Quantity	1995 Value (thousands)	1996 Quantity	1996 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, and shot	1,310	$11,400	586	$4,630
Ferronickel	807	6,590	3,330	32,700
Powder and flakes	1,230	13,900	1,060	12,600
Metallurgical-grade oxide 2/	3,490	7,730	4,210	6,750
Chemicals: 3/				
Catalysts	2,210	83,900	3,250	97,000
Salts 4/	714	10,100	692	7,980
Total	9,750	134,000	13,100	162,000
Unwrought secondary: 5/				
Stainless steel scrap	27,600	325,000	22,800	234,000
Waste and scrap	14,200	58,600	10,900	56,600
Total	41,800	384,000	33,600	290,000
Grand total	51,500	517,000	46,800	452,000
Wrought:				
Bars, rods, profiles and wire	205	2,150	157	2,300
Sheets, strip and foil	117	2,180	188	2,720
Tubes and pipes	154	1,420	95	1,360
Total	,476	5,750	,440	6,370
Alloyed (gross weight):				
Unwrought alloyed ingot	4,170	41,000	5,710	56,600
Bars, rods, profiles and wire	4,920	79,900	4,770	82,300
Sheets, strip and foil	6,380	104,000	8,200	113,000
Tubes and pipes	1,240	28,000	1,270	31,700
Other alloyed articles	2,150	36,500	3,520	53,000
Total	18,900	289,000	23,500	336,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Chemical-grade oxide is included with the "Salts" category.
3/ For the different salts, the nickel contents are assumed to be as follows: chlorides, 25%; sulfates, 22%; other salts, 22%; and oxide, sesquioxide and hydroxide, 65%. The typical catalyst is assumed to have a nickel content of 22%.
4/ Excludes nickel carbonate (see schedule B 2836.99.9050).
5/ The nickel content of waste and scrap is assumed to be 50%, while that of stainless steel scrap has been shown to be about 7.5%.

Sources: Bureau of the Census and Journal of Commerce.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 1996, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

Country	Cathodes, pellets, and briquets, (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 1996	Total 1995	Wrought nickel 4/
Australia	--	2	--	--	108	8	6	124	164	6
Belgium	--	35	--	--	--	158	195	388	2,520	4
Canada	307	707	39	4,030	6,370	4,080	856	16,400	18,600	43
China	--	(5/)	--	--	121	123	26	270	372	3
Colombia	3	12	--	--	15	17	22	69	34	1
Finland	--	(5/)	--	--	30	(5/)	--	30	37	--
France	2	14	--	2	25	8	23	74	280	16
Germany	9	26	--	2	692	17	22	768	730	15
India	--	4	1,590	--	66	134	24	1,820	354	5
Italy	--	4	--	--	(5/)	3	16	23	39	--
Japan	(5/)	44	23	1	1,140	1,940	724	3,880	5,300	14
Korea, Republic of	(5/)	23	--	(5/)	17	5,930	53	6,030	8,010	6
Mexico	175	40	11	7	14	18	278	543	524	145
Netherlands	28	13	--	--	83	124	21	269	1,400	5
South Africa	--	1	359	20	--	993	19	1,390	779	(5/)

See footnotes at end of table.

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TABLE 7--Continued
U.S. EXPORTS OF NICKEL PRODUCTS IN 1996, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

Country	Cathodes, pellets, and briquets, (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 1996	Total 1995	Wrought nickel 4/
Spain	(5/)	2	--	(5/)	--	4,860	3	4,860	5,160	4
Sweden	--	10	--	--	2,010	643	(5/)	2,670	2,380	1
Taiwan	--	11	1,300	--	9	3,110	105	4,540	1,520	3
United Kingdom	7	33	1	6	90	119	78	334	451	77
Other	55	79	(5/)	144	87	457	1,470	2,290	2,930 r/	93
Total	586	1,060	3,330	4,210	10,900	22,800	3,940	46,800	51,500	440

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemical category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.

3/ Chemical-grade oxide is included in the "Chemicals" category.

4/ Not included in "Total."

5/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS 1/

(Metric tons of contained nickel 2/ unless otherwise specified)

Class	1995 Quantity	1995 Value (thousands)	1996 Quantity	1996 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, and shot	118,000	$959,000	113,000	$890,000
Ferronickel	16,700	129,000	16,000	111,000
Flakes	790	4,690	1	55
Powder	8,720	89,100	9,700	101,000
Metallurgical-grade oxide	530	5,110	464	4,220
Chemicals:				
Catalysts	2,420	34,200	1,540	61,500
Salts 3/	1,780	22,100	1,730	22,800
Total	149,000	1,240,000	142,000	1,190,000
Unwrought secondary:				
Stainless steel scrap	3,190	33,800	3,790	28,500
Waste and scrap	4,740	47,100	4,280	35,200
Total	7,930	80,900	8,060	63,800
Grand total	157,000	1,320,000	150,000	1,250,000
Wrought:				
Bars, rods, profiles and wire	170	2,540	242	3,750
Sheets, strip and foil	2,040 r/	23,900 r/	341	9,090
Tubes and pipes	94	2,020	54	1,230
Total	2,310 r/	28,400 r/	636	14,100
Alloyed (gross weight):				
Unwrought alloyed ingot	3,000	28,200	2,780	28,300
Bars, rods, profiles and wire	3,210	39,900	3,920	58,500
Sheets, strip and foil	1,510	22,200	1,520	24,800
Tubes and pipes	1,040	21,000	832	17,500
Other alloyed articles	377	11,500	1,190	18,700
Total	9,140	123,000	10,200	147,800

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The nickel contents are as follows: metallurgical-grade oxide from Australia 90%; elsewhere 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.

3/ Excludes nickel carbonate (see HTSUS 2836.99.5000).

Sources: Bureau of the Census and Journal of Commerce.

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TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total 1996	Total 1995	Wrought nickel 4/
Australia	13,300	1,470	--	67	10	--	24	14,900	13,800	--
Austria	--	117	157	--	--	--	--	274	139	14
Belgium	--	3	--	--	19	--	322	344	554	--
Brazil	118	1	350	--	32	--	--	501	2,800	--
Canada	47,800	6,640	--	369	1,150	1,900	650	58,500	54,400	26
China	--	(5/)	--	--	5	--	22	27	235	1
Colombia	--	--	1,390	--	26	1	1	1,420	2,330	--
Dominican Republic	--	--	9,150	--	135	4	--	9,290	8,270	--
Finland	3,830	437	--	--	--	1	469	4,740	2,870	(5/)
France	1,460	2	--	--	555	5	236	2,260	2,010	88
Germany	147	73	--	--	305	4	289	818	525	408
Japan	301	63	--	--	158	127	507	1,160	459	55
Mexico	--	--	--	--	90	1,600	248	1,940	1,560	1
New Caledonia	--	--	4,160	--	--	--	--	4,160	4,200	--
Norway	24,300	--	--	--	20	--	--	24,300	19,200	--
Russia	17,200	734	418	--	259	1	4	18,600	34,600	--
South Africa	1,170	--	30	--	--	--	--	1,200	2,570	--
United Kingdom	865	109	--	(5/)	819	--	143	1,940	2,740	15
Zimbabwe	1,730	--	--	--	--	--	--	1,730	1,900	--
Other	625	43	323	28	692	139	350	2,200	1,710	28
Total	113,000	9,700	16,000	464	4,280	3,790	3,270	150,000	157,000	636

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts which are assumed to be 22% nickel. The typical catalysts are assumed to have a content of 22%.

3/ Primarily oxide rondelles and sinter.

4/ Not included in "Total."

5/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of nickel content)

Country	1992	1993	1994	1995	1996 e/
Albania (content of ore) e/	150	75	--	--	--
Australia (content of concentrate)	57,683	64,717	78,962	98,467 r/	113,134 3/
Botswana (content of ore milled)	23,000	23,000	19,041	18,672	24,200 3/
Brazil (content of ore)	29,372	32,154	32,663	25,469 r/	25,600
Burma (content of ore)	9	67	50 e/	50 e/	50
Canada (content of concentrate)	186,384	188,080	149,886	180,984	183,059 p/
China (content of concentrate) e/	32,800	30,700	36,900	41,800 r/	43,000
Colombia (content of laterite ore)	23,347	22,831	26,141	24,194	27,700 3/
Cuba (content of oxide, oxide sinter, sulfide) 4/	32,190	30,227	26,926	42,696	51,613 3/
Dominican Republic (content of laterite ore)	42,641	37,423	45,588 r/	44,051 r/	45,000
Finland (content of concentrate)	10,311 r/	8,862 r/	7,652	4,382	4,000
Greece (content of laterite ore)	17,000	12,940	18,821	19,947	20,000
Indonesia (content of ore)	77,600	65,757	81,175	88,183	90,000
Kazakstan e/	8,500	8,500	8,500	9,900 3/	9,800
New Caledonia (content of ore)	113,000	97,092	97,323	121,457	142,200 3/
Norway (content of concentrate)	3,398	3,462	2,938	2,992 r/	3,000
Philippines	13,022	7,663	9,895	15,075	14,700
Russia e/	280,000	244,000 3/	240,000	251,000	230,000
Serbia and Montenegro (content of ferronickel produced)	1,857	443	603	962	2,556 3/
South Africa (content of concentrate)	28,400	29,868	30,751	29,803	33,613 3/
Ukraine (content of ferronickel produced) e/	5,900 3/	3,000 r/	1,400 r/ 3/	1,400 r/	500
United States (content of local ore processed)	6,670	2,460	--	1,560 p/	1,330 3/
Zimbabwe (content of concentrate)	12,378	12,769	13,836	11,721	11,600
Total	1,010,000 r/	926,000 r/	929,000 r/	1,030,000 r/	1,080,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. Between 1992 and 1996, the Republic of Korea, the United States, and five members of the European Union reported receiving ferronickel originating from Macedonia, but definitive information on the output of the Kavadarci operation was not available. North Korea may also have an active nickel mine, but again information is inadequate to make reliable estimates of outputs. Table includes data available through July 22, 1997.

3/ Reported figure.

4/ Data represent nickel plus cobalt content in the ratio of roughly 80 to 1.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country 3/ and product	1992	1993	1994	1995	1996 e/
Albania: Metal e/	50	50	50	50	50
Australia: Unspecified	57,000	55,000	67,000	77,000 r/	74,000 4/
Austria: Ferronickel	3,900	3,200	2,100 e/	2,500 e/	2,000
Brazil: 5/					
Ferronickel	8,742	8,683	8,815	8,497	8,500
Metal	5,926	7,022	7,795	7,179	7,200
Total	14,668	15,705	16,610	15,676	15,700
Canada: Unspecified 6/	135,200	123,140	105,144	121,523	126,593 4/
China: Metal e/	30,800	30,500	31,300	38,900 r/	43,300
Colombia: Ferronickel	20,195	20,181	20,833	24,565	22,934 4/
Cuba: Oxide sinter 7/	16,717	15,999	13,930	21,388	27,024 4/
Czechoslovakia: 8/ Metal 9/	1,621	XX	XX	XX	XX
Dominican Republic: Ferronickel	27,530	23,859	30,766	30,893	30,400 4/
Finland:					
Chemicals	2,890	3,126	4,192	4,000 e/	4,000
Metal	14,781	14,800	16,902	16,927 r/	16,000
Total	17,671	17,926	21,094	20,927 r/	20,000
France:					
Chemicals e/	1,200	1,200	1,200	1,200	1,200
Metal	6,750	9,120	10,041	10,306	8,500
Total e/	7,950	10,300	11,200	11,500	9,700

See footnotes at end of table.

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TABLE 11--Continued
NICKEL: WORLD PLANT PRODUCTION BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

Country 3/ and product	1992	1993	1994	1995	1996 e/
Greece: Ferronickel	15,420	10,934	16,197	17,164	18,000
Indonesia: Ferronickel	5,506	5,266	5,745	10,735	11,000
Japan:					
Ferronickel	57,447	51,120	50,186	69,876 r/	65,374 4/
Metal	22,038	23,108	25,311	26,824	26,564 4/
Oxide sinter	27,520	28,812	34,711	35,966 r/	36,200 4/
Chemicals	2,427	2,258	2,400	2,297	2,344 4/
Total	109,432	105,298	112,608	134,963 r/	130,482 4/
Korea, Republic of: Metal e/	(10/)	(10/)	(10/)	(10/)	(10/)
New Caledonia: Ferronickel	31,895	36,850	39,488	42,200	41,000
Norway: Metal	55,686	56,817	67,955	53,237	61,582 4/
Russia: e/ 11/					
Ferronickel	6,000	6,800	9,800	14,000	10,000
Metal	221,000	167,000	165,000	181,000	175,000
Oxide sinter	15,000	10,200	4,600	4,100 r/	3,000
Chemicals	3,000	2,000	2,000	2,000	2,000
Total	245,000	186,000	181,000	201,000 r/	190,000
Serbia and Montenegro: Ferronickel	1,857	443	603	962	2,556 4/
South Africa: Metal	27,621	29,868	30,751	29,803	33,100
Sweden: Metal e/	500	500	500	500	500
Taiwan: Metal	(10/)	(10/)	(10/)	(10/)	(10/)
Ukraine: Ferronickel e/	5,900 4/	3,000 r/	1,400 r/	1,400 r/	500
United Kingdom: Metal e/	28,000	28,000	28,400 4/	31,800	32,000
United States: Ferronickel	8,960	4,880	--	8,290	15,100 4/
Zimbabwe: Metal 12/	10,349	11,097	13,516	10,864 r/	9,793 4/
Grand total	879,000	795,000	818,000 r/	908,000	917,000
Of which:					
Ferronickel	193,000	175,000 r/	186,000 r/	231,000 r/	227,000
Metal	425,000	378,000	397,000	407,000 r/	414,000
Oxide sinter	59,200	55,000	53,200	61,500 r/	66,200
Chemicals	9,520	8,580	9,790	9,500	9,540
Unspecified	192,000	178,000	172,000	199,000 r/	201,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 22, 1997.

3/ In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Between 1992 and 1996, the Republic of Korea, the United States, and five members of the European Union reported receiving ferronickel originating from Macedonia, but definitive information on the output of the Kavadarci operation was not available. Data supplied by the International Nickel Study Group suggest that, since 1991, Macedonian ferronickel production has ranged from 2,000 to 4,500 metric tons per year of contained nickel. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in metric tons of contained nickel: Australia (estimated): 1992-96--55,000 (revised); Botswana: 1992--18,918; 1993--19,619; 1994--19,042; 1995--18,089; and 1996--23,200; Canada (estimated): 1992-96--40,000; Indonesia: 1992--39,300; 1993--37,000; 1994--48,400; 1995--49,300; and 1996--49,000; New Caledonia: 1992--7,475; 1993--10,883; 1994--10,641; 1995--10,143; and 1996--9,850.

4/ Reported figure.

5/ Brazil is believed to also produce nickel oxide, but information is not available on which to base estimates.

6/ Nickel contained in products of smelters and refineries in forms which are ready for use by consumers.

7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Output of processed sulfide was as follows, in metric tons of contained nickel: 1992--14,116; 1993--12,973; 1994--11,857; 1995--19,456; and 1996--24,589.

8/ Dissolved Dec. 31, 1992.

9/ All production for Czechoslovakia in 1992 came from Slovakia. Production for 1993-96 is estimated to be zero.

10/ Nickel metal production figures for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical oxides and to include them would result in double counting. Metal estimates are as follows in metric tons: the Republic of Korea: 1992-96--10,000; Taiwan: 1992--10,000; 1993--9,000; and 1994-96--10,000.

11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.

12/ Excludes production from matte shipped from Botswana for toll refining.

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FIGURE 1

LONDON METAL EXCHANGE CASH PRICE AND STOCKS

1990-97

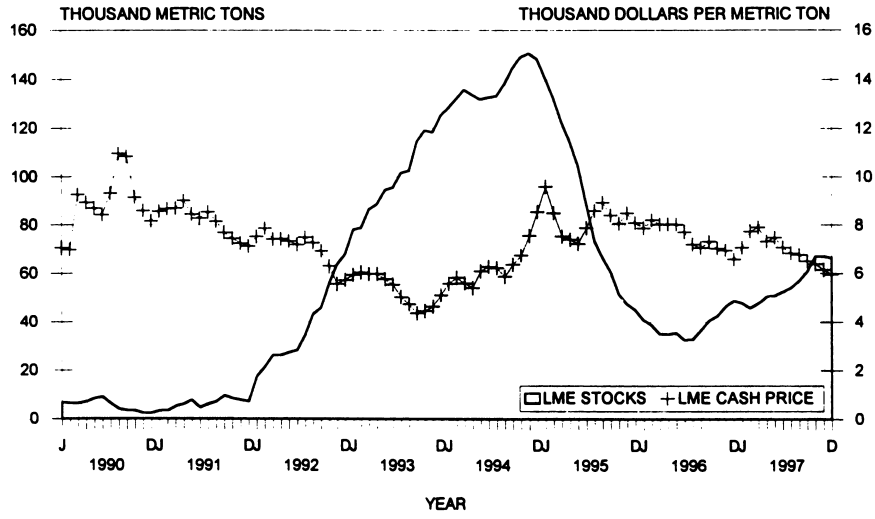
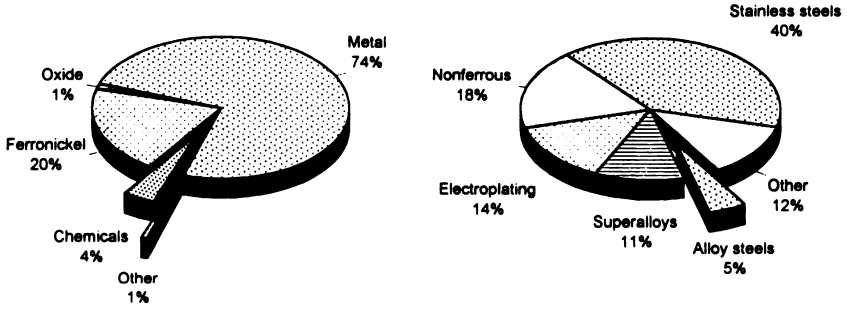


FIGURE 2

U.S. PRIMARY NICKEL CONSUMPTION, BY FORM AND USE

1996



FORM USE

116,000 METRIC TONS

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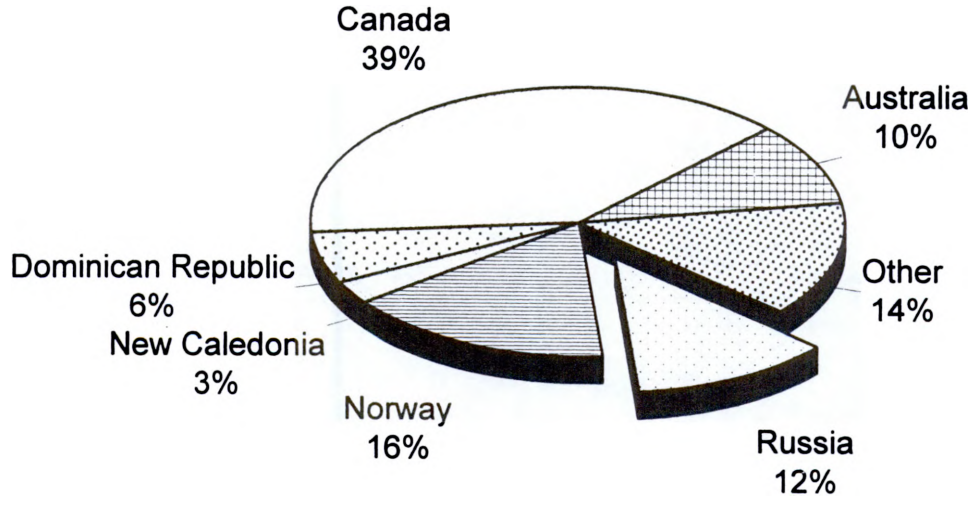
FIGURE 3

COMBINED U.S. PRIMARY AND SECONDARY NICKEL IMPORTS, BY COUNTRY 1996



150,000 METRIC TONS

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NITROGEN

By Jim F. Lemons, Jr.

Nitrogen (N) is an essential element of life, a part of all plant and animal proteins. Crop plants cultivated for both human consumption and as animal feed require nitrogen for proper nutrition and maturation. Some crops such as alfalfa, soybeans, garden peas, and peanuts can convert atmospheric nitrogen into a usable form in a process called "fixation." However, most nitrogen available for crop production comes from decomposing animal and plant waste or from commercially produced fertilizers.

All commercial fertilizers contain their nitrogen in the ammonium and/or nitrate form or in a form that is quickly converted to these forms once the fertilizer is applied to the soil. Nitrates are produced from mineral resources principally in Bolivia and Chile. Commercial production of anhydrous ammonia is based on reacting nitrogen with hydrogen under high temperatures and pressures. The source of nitrogen is always air, which is almost 80% nitrogen. Hydrogen is derived from a variety of raw materials, including water, and crude oil, coal, or natural gas hydrocarbons. Other nitrogen fertilizers are produced from ammonia feedstocks through a variety of chemical processes.

In 1996, there were 25 ammonia producers with 41 plant locations in the United States. Many companies in the fertilizer industry were expanding their operations to include production of all three major plant nutrients—potassium, phosphorus, and nitrogen. Principal changes in the industry included the acquisition of nitrogen producer Arcadian Corp. by the Potash Corp. of Saskatchewan (PCS), and Mississippi Chemical Corp.'s acquisition of the plants of First Mississippi Fertilizer Inc.(Ampro) and of Triad Chemical Co.

Industry statistics for anhydrous ammonia and derivative products were developed by the Bureau of the Census, U.S. Department of Commerce. Summary of production of principal inorganic fertilizers by quarter is reported in the series MQ28B, and industrial gases (including nitrogen) are reported in the quarterly report MQ28C. The Bureau of the Census surveys approximately 250 producers of inorganic fertilizer materials. Final data are subsequently published in a companion annual report MA28B.

Legislation and Government Programs

Two court cases this year held significant interest for manufacturers of urea and ammonium nitrate. In May 1995, a suit filed by the relatives of people killed in the April 1995 Oklahoma City Federal Building bombing alleged that ICI Explosives USA had been negligent in allowing ammonium nitrate to be sold, knowing that it could be used in making explosives, without adding chemical desensitizers that might make the material less reactive. One technical question in this litigation is the feasibility of limiting explosive potential in large-scale volumes with the addition of monoammonium or diammonium phosphate or calcium ammonium nitrate. This lawsuit was followed by similar litigation against Arcadian, Norsk Hydro, and Dyno Nobel by the New York and New Jersey Port Authority for allegedly supplying nondesensitized fertilizers, which were ultimately used in the World Trade Center bombing of February 1993. By midyear, the Oklahoma bombing case against ICI Explosives had been dismissed by the Oklahoma District Court, which ruled that ICI had no obligation to anticipate and guard against the willful and criminal misuse of its products. The final impact of this dismissal on the second court case has yet to be determined (Nitrogen, 1996a, e, f).

The final Environmental Protection Agency (EPA) rule for preparing an Industry Risk Management Plan was signed May 24. The rule covers plants, terminals, and dealerships that handle more than the threshold limits of 4.5 tons of anhydrous ammonia, or 9 tons of aqua ammonia in 20% solution or 6.8 tons of nitric acid in concentrations of more than 80%. The rule requires these companies to perform a hazard assessment for each location, set up a release prevention program, and draft an emergency response plan. This combined Industry Risk Management Plan is to be submitted in 1999 (Green Markets, June 17, 1996)

Production

Production of anhydrous ammonia (82.2% N) increased 12% in 1996 to 14.6 million metric tons of contained nitrogen compared with that in 1995. Eighty-six percent of the production was for use as a fertilizer; the remaining 14% was used in other chemical and industrial sectors. (*See tables 1 and 2.*) Much of the increase in production was used domestically. Prices returned to values comparable with those of 1994 at $225 per short ton, f.o.b Gulf Coast spot prices.

The United States remained the worlds second largest producer and consumer of elemental and fixed types of nitrogen following China. Urea, ammonium phosphates, ammonium nitrate, ammonium sulfate, and nitric acid are the major downstream products produced from ammonia in the United States, in order of importance. Their combined production was 10.3 million tons of contained nitrogen with urea accounting for one-third of the production. (*See table 3.*)

Ammonia producers in the United States operated at or above design capacity. Nearly 59% of total U.S. ammonia production capacity was concentrated in the States of Louisiana

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(39%), Oklahoma (14%), and Texas (6%), owing to large indigenous reserves of natural gas feedstock. Farmland Industries Inc.; Arcadian Corp.; Terra International, Inc.; CF Industries Inc.; Mississippi Chemical Corp., and Union Chemical Co., in order of importance, accounted for 68% of total U.S. ammonia capacity. *(See table 4.)*

Mississippi Chemical Corp. acquired the fertilizer operations of First Mississippi Corp. including the Ampro facility at Donaldsville, LA, which is expanding annual ammonia production capacity by 25% to more than 540,000 tons. This will be the first U.S. instillation to retrofit a plant utilizing the Kellogg Advanced Ammonia Process. (Nitrogen, 1996b) (Chemical Marketing Reporter, 1996e). The acquisition gave Mississippi Chemical full ownership of Triad Chemical with its anhydrous ammonia plant production capacity of 420,000 tons and a urea plant annual production of 500,000 tons.

In addition to these acquisitions, Mississippi Chemical Corp. announced expansion of its nitrogen fertilizer manufacturing facilities at Yazoo City, MS. Plans include a new 450-ton-per-day ammonia plant based on the ICI Katalco's Leading Concept for Ammonia process and modification of the ammonium nitrate plant from 680,000 to 860,000 tons per year. The expansion is expected to be fully operational by early 1998 (Mississippi Chemical Corporation, 1996; Nitrogen, 1996d).

PCS acquired Arcadian Corp., the largest producer of nitrogen fertilizer in the Western Hemisphere (Fertilizer Markets, 1996a). Arcadian Corp. had been in the process of expanding ammonia capacity at its plant in Augusta GA, from 1,500 to 1,700 tons per day (Fertilizer Focus, 1996). It is also expanding granular urea capacity at its plant in Lima, OH, by 140,000 tons per year and raising ammonia plant capacity to 635,000 tons per year, an increase of 9% (European Chemical News, 1996a). These expansions were expected to be completed by 1998.

The Dakota Gasification Co. (DGC) started up a 136,000-ton- per-year ammonium sulfate line at its Beulah, ND, plant. This process utilizes a forced oxidation technology developed by General Electric that reacts sulfur dioxide with ammonia and air in a two-stage recycling process. The process utilizes the sulfur dioxide waste from the unique DGC coal gasification plant and recirculating waste heat to reduce costs to competitive levels (Nitrogen, 1996c).

The Port Neal, IA, ammonia production plant of Terra International Inc. commenced ammonia production in December 1995. The 300,000-ton-per-year plant had been severely damaged in an explosion in December 1994 (Fertilizer Focus, 1996). Its nitrogen solutions plant came on-line in May 1996 (C&EN, 1997). Terra is also expanding production of nitric acid, which will allow for the upgrade of ammonia production to urea-ammonium nitrate (UAN) increasing UAN capacity from 470,000 to 735,000 tons per year.

Agrium Inc. (US) and Viridian Inc. (Canada) announced in October their agreement to merge, which will create one of the largest fully integrated fertilizer production and marketing corporations in North America. The corporation will be known as Agrium Inc. (Chemical Marketing Reporter, 1996).

Environment

Both the ammonium and nitrate forms of N are highly soluble in water and are readily available for crop plant uptake. Ammonium is held by soil particles therefore not subject to movement down through the soil during periods of rainfall or irrigation. Nitrates, however, do move downward with soil water. This leaching process can lead to nitrate accumulation in ground water. As soils are warmed during the growing season, the ammonium form of nitrogen is subject to conversion to nitrate in a process called "nitrification." Most of the ammonium not used by the crop is eventually converted to nitrate. Nitrogen stabilizers and nitrification inhibitors can slow the conversion of soil ammonium to nitrate. Best management practices to increase nitrogen use efficiency and reduce nitrate leaching include application of fertilizer as close to the time of actual crop use, multiple applications, terracing, grass waterways, and strip cropping.

A study released in April provides the first detailed analysis of the Chesapeake Bay air shed. The work concentrates on nitrogen as one of two major pollutants affecting the bay, causing algae blooms and oxygen "dead spots" that harm marine life. Although most of the nitrogen in the bay comes from land sources, which include sewage effluent, chemical runoff from farmlands, and suburban development, this study indicated that 20% to 35% of the total nitrogen pollution may come from air pollution. The study seems to indicate that a significant portion of this pollution is from Midwestern powerplants and other smokestack industries, some as far as 650 kilometers from the bay. Further analysis of these results and possible techniques to overcome the problems is an ongoing field of research and discussion (Shields, 1996).

A survey reported annually to the EPA and commissioned by the Fertilizer Institute indicates that releases of ammonia and other chemicals from nitrogen fertilizer facilities decreased 3.6% during 1994 as compared to the previous year and down 5.6% as a ratio to tons produced. Since Toxic Release Inventory (TRI) reporting began in 1987, the nitrogen fertilizer industry has reduced emissions 74.6% as a ratio of pounds released per pound produced. This reduction has been due to the installation of new scrubbers, neutralizer concentrators that capture fumes from the process of mixing ammonia and nitric acid, and heat saturators that reduce a plant's steam requirements by recycling condensate. (Chemical Marketing Reporter, 1996d).

Consumption

Apparent consumption returned to values comparable with 1994, at 16.6 million tons of N; an increase of 8% over 1995 values. *(See table 1.)* Apparent consumption is calculated as the production plus imports minus exports, adjusted to reflect any changes in stocks.

Consumption of nitrogen fertilizers in the United States for the 1996 crop year (ending June 30, 1996) is reported in table 5. Consumption increased 4% from 1995 values to 11.1 million

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tons of nitrogen. Anhydrous ammonia is the principal fertilizer product representing 32% of fertilizer consumption.

Urea and UAN solutions together constitute 38% of fertilizer consumption during the 1996 crop season. Urea is typically 45.9% N, and UAN solutions are typically 29.8% to 29.9% N. In the industrial sector, urea is used extensively as a protein supplement in ruminant animal feeds, for the production of urea-formaldehyde adhesives, and for the synthesis of plastics and resins.

Ammonium nitrate was used primarily in solid and liquid fertilizers, in industrial explosives, and as blasting agents. Total production of ammonium nitrate was 2.6 million tons of contained nitrogen. (*See table 3.*) After World War II, ammonium nitrate became the leading solid nitrogen fertilizer in the United States and worldwide, and remained such until about 1975, when its use was surpassed by synthetic urea. In 1996, approximately 25% of ammonium nitrate production was used in fertilizer consumption. Ammonium nitrate containing 33.9% N constituted 6% of 1996 fertilizer consumption.

Ammonium sulfate was used mostly as a fertilizer material, valued for its nitrogen content (21.2% N) and for its readily available sulfur content (24.3% sulfur). It is commonly produced as a byproduct of caprolactam production, an intermediate in nylon manufacture. Since the introduction of ammonium nitrate and urea, the relative importance of ammonium sulfate worldwide has steadily decreased. In the 1996 crop year, fertilizer consumption of ammonium sulfate based on nitrogen content was 2% of the market. Nonfertilizer uses constitute approximately 40% of the total ammonium sulfate market (on a contained nitrogen basis), including food processing, fire control, tanning, and cattle feed.

Nitric acid production is shown in table 3. Nitric acid is used in salt formation reactions to produce metal nitrates and in metal degreasing, treating and pickling for graphic and galvanic industries. Nitration reactions with benzene, phenol, and toluene produce dyestuffs, pharmaceutical products, trinitrotoluene (TNT) explosives, and disinfectants. Esterification reactions with glycol, glycerol, and cellulose produce nitroglycerine explosives (dynamite), celluloid, and nitrocellulose lacquers. Oxidation reactions with toluene, p-xylene, and cyclohexanone produce polyurethanes and polyester fibers (nylon), respectively.

Acrylonitrile was used in the production of acrylic fibers, high impact acrylonitrile-butadiene-styrene (ABS) plastics, nitrile elastomers, and nylon fibers, resins, and plastics. (*See table 3.*)

Other uses of ammonia are for the production of amines, cyanides, and methyl methacrylate polymers (plexiglass); liquid home and industrial cleaners; pulp and paper products; industrial refrigeration; metallurgy; and as a propellant in vehicular air bags.

Elemental nitrogen is used extensively by the electronics, metals, food, and aerospace industries because of its unique inert and cryogenic properties. Nitrogen can be used to prevent fires and explosions as a purging agent for cleaning and processing equipment, and as a controlling atmosphere for annealing and heat treating and other metal preparation processes where oxygenation is a concern.

Stocks

At yearend 1996, stocks totaled 1.5 million tons N, comparable with 1995 stocks of 1.6 million tons N. (*See table 6.*)

Transportation

Ammonia was transported by refrigerated barge, rail, pipeline, and truck. Three companies serve 11 States with pipelines 4,900 kilometers (km) in length, with 4,800 km of river barge transport, and by rail and truck used primarily for interstate or local delivery.

Koch Industries operated the Gulf Central ammonia pipeline from the Gulf of Mexico (Louisiana) to the Midwest as far north as Iowa, covering 3,065 km, and to the east to Huntington, OH. The annual capacity of this pipeline was about 2 million tons, with a storage capacity of more than 1 million tons.

Mapco Ammonia Pipeline Inc. operated its own pipeline and its subsidiary, Mid-America Pipeline System, that extended from Borger in northern Texas to Mankato in southern Minnesota, covering 1,700 km. The Mapco pipeline had an annual capacity of more than 1 million tons and about 500,000 tons of ammonia storage capacity.

CF Industries Inc. and Cargill Fertilizer, Inc. jointly operated the Tampa Bay Pipeline (TBP) system with a 135-km route. TBP moved nitrogen compound and ammonium phosphate for fertilizer producers in Hillsborough and Polk Counties, FL.

Capacities for trucks and rail cars are usually 20 and 100 tons, respectively. Depending on the product loaded and the volume of the container, barges can accommodate from 400 to 2,000 tons.

Ammonium nitrate is transported by rail, road, and water, but its transportation on U.S. navigable waterways is restricted. Urea is shipped either in bulk or as bagged material.

Prices

Anhydrous ammonia prices increased 11 to 15% in 1996 in relation to 1995 prices as quoted f.o.b. barge Gulf Coast and Corn Belt. (*See table 7.*) Ammonium nitrate prices f.o.b. Corn Belt remained steady at prices ranging from $160 to $170 per short ton. Urea prices however decreased about 10% to 17% over that same time period as reported f.o.b. Corn Belt (prilled) and Gulf Coast (granular and prilled). Diammonium phosphate prices also decreased approximately 16%-17% from 1995 quotes f.o.b. central Florida.

Foreign Trade

Anhydrous ammonia exports were up by 37% compared to those of 1995. Almost 75% was imported by the Republic of Korea. U.S. anhydrous ammonia imports dropped 6.5% in 1996. Trinidad and Tobago and Canada supplied 89% of total

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U.S. ammonia import tonnage. *(See tables 8 and 9.)*

Trade of other nitrogen materials is shown in tables 10 and 11. Exports of Urea increased 67% in 1996 compared with those of 1995. Export markets also increased for monoammonium phosphate and mixed chemical fertilizers. Imports of other U.S. nitrogen compounds in 1996 remained similar to 1995 tonnages.

World Review

Anhydrous ammonia and other nitrogen materials were produced in more than 80 countries. Global ammonia production in 1996 increased slightly relative to 1995 levels. Total ammonia production was nearly 100 million tons contained nitrogen in 1996, based on data reported by the U.S. Geological Survey. About 24% of global ammonia production originated in China; Asia contributed 39% of world total ammonia production. The United States and Canada represented 19% of the global total, with the United States accounting for 79% of the region. Countries in the former U.S.S.R. were 12% of the total; Western Europe, 9%; Middle East, 6%; Latin America, 6%; and Eastern Europe, Africa, and Oceania contributed the rest. *(See table 12.)*

World ammonia exports in 1996 increased slightly compared with those of 1995, to 10.9 million tons of contained nitrogen. Russia, Trinidad and Tobago, Ukraine, and Canada accounted for 58% of the world total, in order of importance. Western Europe imported 35% of global ammonia trade, followed by the United States (30%) and Asia (16%) (International Fertilizer Industry Association, 1996).

World urea production increased 4% to 43 million tons contained nitrogen in 1996. China and India accounted for 37% of 1996 world production. The United States and Canada produced about 12% of the total. Global urea exports remained steady at 11.2 million tons N in 1995 and 1996. Russia and Ukraine accounted for 26% of total exports; Middle East, 19%; Eastern Europe, 12%; Canada and the United States, 15%; Asia, 9%; Western Europe, 8%; Latin America, 8%; and Africa and Oceania shipped minor tonnages (International Fertilizer Industry Association, 1996). Asia accounted for 53% of global urea imports; Latin America accounted for 12%, North America accounted for 11%, and Western Europe accounted for 11%.

Brazil.—During July, Brazilian producer Petrobras revamped its ammonia and urea plants at Laranjeiras, in Sergipe State, increasing ammonia capacity from 1,000 to 1,250 tons per day and increasing urea capacity from 1,450 to 1,600 tons per day (Fertilizer Week, 1996).

Canada.—In 1996, Canada produced 3.8 million tons of contained nitrogen as anhydrous ammonia. Exports increased 10% to 926,000 tons. Urea production was 1.5 million tons N, and exports increased 25% to 963,000 tons N.

Continental Nitrogen and Resources Corp. is building a 136,000-ton-per-year industrial-grade ammonium nitrate plant at Brandon, Manitoba. This plant will be the first in North America to use a prilling tower recirculating air loop (Chemical Marketing Reporter, 1996).

Chile.—The only commercially exploited mineral to be used as a fertilizer in Chile is nitrate. It occurs as an impure sodium nitrate, known as caliche. Sociedad Quimica y Minera de Chile SA (SQMC), the only producer of natural nitrates, exports to Latin America, China, North America, and Western Europe. The principal product is sodium nitrate with 16% nitrogen content, known as Chilean nitrate or Chilean saltpeter. Farmers often refer to it simply as soda. SQMC produces about 840,000 tons per year of nitrate, 400,000 tons of sodium sulfate, and 5,000 tons of iodine.

The Minera Yolda Mine in northern Chile had planned to start operations in September or October 1996, with plant operations to produce either 272,000 tons per year of sodium nitrate or 323,000 tons per year of potassium nitrate. The project was delayed in 1996 when the contractor experienced financial difficulties (Phosphorus & Potassium, 1996).

China.—China's production of urea in 1996 increased 12% to 9 million tons contained nitrogen. Imports were at 2.9 million tons N, approximately 27% of world trade.

China had forecast lower urea imports, in part because five large new urea plants came into production in 1996. Plants on Hainan Island and at Huehato in Inner Mongolia started trial production towards the yearend (Chemical Marketing Reporter 1996). In July, a new ammonia/urea complex came on-stream in Sichuan Province.

Italy.—Norsk Hydro, one of Europe's largest producers of fertilizers, has strengthened its position in the Southern European fertilizers market with the acquisition of the fertilizer production units of EniChem in Ferrara and Ravenna. The Ferrara plant includes a 500,000-ton-per-year ammonia plant and a urea plant of similar capacity. The Ravenna plant has a 360,000-ton-per-year compounded nitrogen-phosphate-potassium fertilizer operation and a 500,000-ton-per-year calcium ammonium nitrate plant. (Chemical Engineering News, 1996b). In addition, Norsk Hydro has acquired Terni Industrie Chimiche, a nitrogen fertilizer unit of EniChem. This purchase involves plants with annual capacities of 110,000 tons of ammonia, 120,000 tons of urea, and 120,000 tons of calcium nitrate and speciality fertilizers (Chemical Engineering News, 1996a)

Mexico.—Production of ammonia increased 3.1% to 2.1 million tons contained nitrogen. Exports, however, dropped 35% to 167,000 tons N. An explosion of the country's largest gas complex in Cactus, Chiapas, on July 26 cut the nation's natural gas supply by one third and interrupted the supply of ammonia for export which has typically been about 25,000 tons per month of ammonia (European Chemical News, 1996b).

Russia.—A new 2.3-million-ton-per-year terminal was officially opened in March at Murmansk in the Koal Inlet of the Barents Sea, in the extreme northeast of Russia. The terminal was designed to accommodate exports of urea, potash, and phosphate fertilizers. Ammonia storage tanks capable of handling 907,000 tons per year and handling equipment were also being installed. Principal stakeholders are Murmansk Commercial Port, Agrochimexport, and Perm Minudobreniya (Fertilizer Focus, 1996).

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Saudi Arabia.—Safco planned to double its existing capacity at Jubail with the completion of a new ammonia/urea complex in 1999. The plant will consist of a 453,000-ton-per-year ammonia and 544,000-ton-per-year granular urea plant. The plant will use Stamicarbon technology for the urea process, Brown & Root process for ammonia, and Hydro Agri's granulation technology (Fertilizer Week, 1997). Saudi Arabia is the predominant fertilizer producer in the Arab Gulf, and the country has three fully or partially state-owned fertilizer companies that come under the auspices of Saudi Arabian Basic Industries Co.

Trinidad and Tobago.—In 1996, Trinidad and Tobago produced 1.8 million tons of contained nitrogen as ammonia an increase of 6% compared with that of 1995. Exports increased 5% to 1.6 million tons N in ammonia.

Mississippi Chemical Corp. began construction of a 1,800-ton-per-day ammonia plant that will be the largest single-train ammonia production facility in the world. The plant will incorporate the Kellogg Advanced Ammonia Process. It is expected to be operational by early 1998 (Mining Engineering, 1996). Arcadian's 255,000-ton-per-year ammonia plant at Point Lisas initiated production in April (Fertilizer Markets, 1996).

Current Research and Technology

Researchers at the Tokai University in Kanagawa, Japan, have discovered that using urea as the gaseous nitrogen source in the heavy doping of a diamond cathode can provide the source for a new generation of high-performance miniaturized vacuum tubes. These tubes can be powered from a single commercial 1.5-volt battery and will find application in microelectronics and displays (Chemical and Engineering News, 1996c).

Outlook

One of the current global trends is the regionalization of markets, particularly in ammonia where freight costs are higher to cover refrigeration. Thus, markets for the former U.S.S.R. tend to be Europe and North Africa, while the Middle East tends to dominate as a supply source for south and east Asia.

The use of nitrogen containing fertilizers is expected to increase during the next few years in response to expected increases in crop planting and fertilizer use. The estimated amount of that growth, however, covers a wide range. The Washington, DC, based Fertilizer Institute predicts moderate growth of 1% to 3%, while stock analysts have predicted growth of up to 7% within the United states. These growth predictions are based in part on the expected continued demand from South America and south and east Asia (Chemical and Engineering News, 1997; Nitrogen, 1996d).

Urea production is expected to increase by 12% by the end of the century. Asia has become the main destination of urea, with China and India being the two largest consumers. New global capacity is expected as most of the debottlenecking and upgrading of older urea plants has been completed. New construction is expected in China, India, and the Middle East.

Another of the major changes is the continuing increase in market share for granular urea which has a more consistent size than prilled urea. Also, granular urea has a release and yield that is more constant (Nitrogen, 1996d).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT AMMONIA STATISTICS 1/ 2/

(Thousand metric tons of contained nitrogen unless otherwise specified)

	1992	1993	1994	1995	1996 p/
United States:					
Production	13,400	12,600	13,400	13,000 r/	14,600
Exports	354	378	215	319	435
Imports for consumption	2,690	2,660	3,450	2,630	2,460
Consumption, apparent 3/	15,600	15,100	16,500	15,300 r/	16,600
Stocks, Dec. 31; producers'	1,060	852	956	959 r/	953
Average annual price per ton product, f.o.b. gulf coast 4/	$106	$121	$211	$191	$225
Net import reliance 5/ as a percent of apparent consumption	14	17	19	15	12
Natural gas price; wellhead 6/	$1.74	$2.04 r/	$1.85 r/	$1.55 r/	$2.25
World:					
Production	93,400 r/	91,700 r/	92,200 r/	96,100 r/	97,500 e/
Trade 7/	9,270	9,060	10,000	10,800	11,000

e/ Estimated. p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits, except prices.
2/ Synthetic anhydrous ammonia, calendar year data, Bureau of the Census; excludes coke oven byproduct.
3/ Calculated from production, plus imports minus exports, and industry stock changes.
4/ Green Markets, Fertilizer Market Intelligence Weekly, Pike & Fischer, Inc.
5/ Defined as imports minus exports, adjusted for industry stock changes.
6/ Monthly Energy Review, U.S. Department of Energy. Average annual cost at wellhead in dollars per thousand cubic feet.
7/ International Fertilizer Industry Association Statistics World Anhydrous Ammonia Trade.

TABLE 2
FIXED NITROGEN PRODUCTION IN THE UNITED STATES 1/

(Thousand metric tons of contained nitrogen)

	1995	1996 p/
Anhydrous ammonia, synthetic: 2/		
Fertilizer	11,600	12,600
Nonfertilizer	1,410 r/	1,930
Total	13,000 r/	14,600

p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Current Industrial Reports, MA28B, M28B, and MQ28B, Bureau of the Census.

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TABLE 3
MAJOR DOWNSTREAM NITROGEN COMPOUNDS
PRODUCED IN THE UNITED STATES 1/ 2/

(Thousand metric tons)

Compound	1995	1996 p/
Urea:		
Gross weight	7,370 r/	7,370
Nitrogen content	3,440 r/	3,440
Ammonium phosphates: 3/		
Gross weight	16,500 r/	16,900
Nitrogen content	2,850 r/	2,810
Ammonium nitrate:		
Gross weight	7,700 r/	7,550
Nitrogen content	2,700 r/	2,640
Ammonium sulfate: 4/		
Gross weight	2,400 r/	2,420
Nitrogen content	509 r/	514
Nitric acid, direct use: 5/		
Gross weight	1,770 r/	1,740
Nitrogen content	407 r/	400
Acrylonitrile:		
Gross weight	1,450	1,380 6/
Nitrogen content	390	370 6/
Caprolactam:		
Gross weight	714	725 6/
Nitrogen content	93	94 6/
Total:		
Gross weight	37,900 r/	38,100
Nitrogen content	10,400 r/	10,300

p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Ranked in relative order of importance by nitrogen content.
3/ Diammonium phosphate (DAP), monoammonium phosphate (MAP), and other ammonium phosphates.
4/ Excludes coke plant ammonium sulfate.
5/ Gross nitric acid production netted for use in production of ammonium nitrate.
6/ Data based on first two quarters of 1996, doubled for total year. Reporting by ITC was discontinued after the second quarter.

Sources: Bureau of the Census and International Trade Commission.

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TABLE 4
DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 1996 1/

(Thousand metric tons per year of ammonia)

Company	Location	Capacity 2/
Agrium Inc.	Borger, TX	439
Air Products and Chemicals Inc.	Pace Junction, FL	46
Allied Signal Inc.	Hopewell, VA	409
Arcadian Corp.	Augusta, GA	576
Do.	Clinton, IA	237
Do.	Geismar, LA	501
Do.	LaPlatte, NE	182
Do.	Lima, OH	523
Do.	Woodstock, TN	356
Avondale Ammonia 3/	Fortier, LA	399
Borden Chemicals Inc.	Geismar, LA	364
CF Industries Inc.	Donaldsonville, LA	1,740
Coastal Chem, Inc.	Cheyenne, WY	172
Coastal St. Helens Chemical 4/	St. Helens, OR	85
Dakota Gasification Co.	Beulah, ND	91
E. I. du Pont de Nemours & Co. Inc.	Beaumont, TX	433
Farmland Industries Inc.	Beatrice, NE	255
Do.	Dodge City, KS	255
Do.	Enid, OK	919
Do.	Fort Dodge, IA	241
Do.	Lawrence, KS	409
Do.	Pollock, LA	459
Green Valley Chemical Corp.	Creston, IA	32
IMC-Agrico Co.	Faustina (Donaldsonville), LA	482
IMC Nitrogen Company 5/	East Dubuque, IL	269
J. R. Simplot Co.	Pocatello, ID	93
Koch Industries	Sterlington, LA	1,110
LaRoche Industries Inc.	Cherokee, AL	159
Mississippi Chemical Corp. 6/	Yazoo City, MS	455
Do.	Donaldsonville (Ampro), LA	500
Do.	Donaldsonville (Triad), LA	409
Monsanto Co.	Luling, LA	446
Nitromite Fertilizer	Dumas, TX	128
Shoreline Chemical	Gordon, GA	31
Terra International, Inc.	Blytheville, AR	364
Do.	Port Neal, IA	319
Do.	Verdigris, OK	955
Do.	Woodward, OK	446
Union Chemical Co. (Unocal)	Finley, WA	150
Do.	Kenai, AK	1,180
Wil-Grow Fertilizer Co.	Pryor, OK	86
Total		16,700

1/ Data are rounded to three significant digits; may not add to total shown.
2/ Engineering design capacity adjusted for 340 days per year of effective production capability.
3/ Joint venture between American Cyanamid and LaRoche Industries Inc. formed in 1994.
4/ Plant formally owned by Chevron Chemical Co.
5/ Plant formally owned by Phoenix Chemical Co.
6/ Plants formally owned by First Mississippi Fertilizer Inc. (Ampro) and Triad Chemical Co.

Sources: International Fertilizer Development Center (IFDC); North American Fertilizer Capacity, Ammonia, Apr. 1997. Blue, Johnson and Associates, North American NPK Plants and Capacities, Foster City, CA.

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TABLE 5
U.S. NITROGEN FERTILIZER CONSUMPTION,
BY PRODUCT TYPE 1/ 2/

(Thousand metric tons nitrogen)

Fertilizer material 3/	1995	1996 p/
Single-nutrient:		
Anhydrous ammonia	3,240	3,590
Nitrogen solutions 4/	2,510 r/	2,570
Urea	1,680	1,630
Ammonium nitrate	581 r/	646
Ammonium sulfate	191 r/	200
Aqua ammonia	72	69
Other 5/	235 r/	251
Total	8,510 r/	8,960
Multiple-nutrient 6/	2,160 r/	2,170
Grand total	10,700 r/	11,100

p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Fertilizer years ending June 30.
3/ Ranked in relative order of importance by product type.
4/ Principally urea-ammonium nitrate (UAN) solutions, %N 29.9.
5/ Includes other single-nutrient nitrogen materials, all natural organics, and statistical discrepencies.
6/ Various combinations of nitrogen (N), phosphate (P), and potassium (K): N-P-K, N-P, and N-K.

Source: Commercial Fertilizers. Prepared as a cooperative effort by The Fertilizer Institute, and the Association of American Plant Food Control Officials, Dec. 1996.

TABLE 6
U.S. PRODUCER STOCKS OF
FIXED NITROGEN COMPOUNDS
AT YEAREND 1/ 2/

(Thousand metric tons nitrogen)

Material 3/	1995 r/	1996 p/
Ammonia	959	953
Nitrogen solutions 4/	213	275
Urea	166	89
Ammonium phosphates 5/	118	87
Ammonium nitrate	62	65
Ammonium sulfate	60	42
Total	1,580	1,510

p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Calendar year ending Dec. 31.
3/ Ranked in relative order of importance.
4/ Urea-ammonium nitrate and ammoniacal solutions.
5/ Diammonium, monoammonium, and other ammonium phosphates.

Source: Current Industrial Reports, MA28B and MQ28B, Bureau of the Census.

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TABLE 7
PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS
AT YEAREND

(Per short ton product)

Compound	1995	1996
Ammonium nitrate; f.o.b. Corn Belt 1/	$162-$170	$160-$170
Ammonium sulfate; f.o.b. Corn Belt 1/	124-136	119-130
Anhydrous ammonia:		
F.o.b. Corn Belt	205-220	233-245
F.o.b. Gulf Coast 2/	185-195	225
Diammonium phosphate; f.o.b. central Florida	212-215	177-180
Urea:		
F.o.b. Corn Belt, prilled	220-235	197-210
F.o.b. Gulf Coast, granular 2/	217-222	188-190
F.o.b. Gulf Coast, prilled 2/	217-220	181-184

1/ Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio.
2/ Barge, New Orleans.

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 23, 1996 and Jan. 6, 1997.

TABLE 8
U.S. EXPORTS OF ANHYDROUS AMMONIA,
BY COUNTRY 1/

(Thousand metric tons ammonia)

Country	1995	1996 p/
Korea, Republic of	321	399
Morocco	--	28
Belgium	--	26
China	(2/)	18
Mexico	3	16
Canada	8	15
Costa Rica	11	10
Colombia	--	7
Senegal	--	7
Taiwan	14	1
Brazil	19	--
Other 3/	11 r/	3
Total 4/	387	530

p/ Preliminary. r/ Revised.
1/ Value data suppressed by Bureau of the Census. Ranked in relative order of importance by country and geographics.
2/ Less than 1/2 unit.
3/ 1995 includes 14 countries, 1996 includes 13 cpuntries.
4/ Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

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TABLE 9
U.S. IMPORTS OF ANHYDROUS AMMONIA,
BY COUNTRY AND REGION 1/

(Thousand metric tons ammonia and thousand dollars)

Country or region 2/	1995 Gross weight	1995 Value 3/	1996 p/ Gross weight	1996 p/ Value 3/
Trinidad and Tobago	1,520	331,000	1,470	298,000
Canada	1,150	181,000	1,210	206,000
Russia	NA	179,000	NA	84,000
Ukraine 4/	NA	70,700	NA	144,000
Mexico	252	53,000	176	34,600
Latvia	101	24,300	--	--
Venezuela	74	15,800	37	7,300
Middle East 5/	45 r/	10,500 r/	--	--
West Europe 6/ 7/	36	9,070	34	7,000
Far East 8/ 9/	2	151	32	6,670
Brazil	--	--	25	4,800
Total	3,200	877,000	2,990	793,000

p/ Preliminary. r/ Revised. NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Ranked in relative order of importance by country and region.
3/ C.i.f. value.
4/ Independent republic of the former U.S.S.R., effective Jan. 1992.
5/ In 1995 includes Kuwait, Algeria, and Saudi Arabia, in order of importance.
6/ In 1995 includes the United Kingdom, the Netherlands, and Germany, in order of importance.
7/ In 1996 includes Germany and Greece.
8/ In 1995 value is for Japan.
9/ In 1996 includes Indonesia, Thailand, and Taiwan, in order of importance.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 10
U.S. EXPORTS OF MAJOR NITROGEN COMPOUNDS IN 1996 1/

(Thousand metric tons)

Compound	1995 Gross weight	1995 Nitrogen content	1996 p/ Gross weight	1996 p/ Nitrogen content
Fertilizer materials:				
Ammonium nitrate 2/	90	30	62	21
Ammonium sulfate 2/	917	193	824	173
Anhydrous ammonia	387	319	530	435
Diammonium phosphate	10,100	2,140 r/	7,920	1,680
Monoammonium phosphate	1,200	145	1,510	183
Urea	881	406	1,470	675
Mixed chemical fertilizers 3/	295	47	417	66
Total	13,800	3,280 r/	12,700	3,230

p/ Preliminary. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes industrial chemical products..
3/ Harmonized codes 3105.10.0000 and 3105.20.0000.

Source: Bureau of the Census.

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TABLE 11
U.S. IMPORTS OF MAJOR NITROGEN COMPOUNDS IN 1996 1/

(Thousand metric tons and thousand dollars)

Compound	1995			1996 p/		
	Gross weight	Nitrogen content	Value 2/	Gross weight	Nitrogen content	Value 2/
Fertilizer materials:						
Ammonium nitrate 3/	721	245	103,000	718	251	110,000
Ammonium nitrate-limestone mixtures	74	20	9,340	75	20	11,200
Ammonium sulfate 3/	434	91	40,700	373	79	38,300
Anhydrous ammonia 4/	3,200	2,630	877,000	2,990	2,460	793,000
Calcium nitrate	NA	NA	NA	(5/)	(5/)	10,200
Diammonium phosphate	21	4	6,010	77	16	18,300
Monoammonium phosphate	NA	NA	NA	181	22	52,400
Nitrogen solutions	628	189	83,000	877	264	119,000
Potassium nitrate	NA	NA	NA	30	4	9,990
Potassium nitrate-sodium nitrate mixtures	NA	NA	NA	22	3	3,930
Sodium nitrate	NA	NA	NA	99	16	20,000
Urea	2,940	1,350	487,000	2,520	1,170	447,000
Mixed chemical fertilizers 6/	NA	NA	NA	86	10	26,400
Other ammonium phosphates	NA	NA	NA	NA	NA	NA
Other nitrogenous fertilizers 7/	NA	NA	NA	125	37	17,400
Total	8,010	4,500 r/	1,610,000	8,170	4,400	1,680,000

p/ Preliminary. r/ Revised. NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Import values c.i.f.
3/ Includes industrial chemical products.
4/ Includes industrial ammonia.
5/ Less than 1/2 unit.
6/ Harmonized codes 3105.10.0000 and 3105.20.0000.
7/ Codes 3101.00.0000, 3102.29.0000, 3102.60.0000, 3102.90.0000, and 3105.90.0050.

Source: Bureau of the Census.

TABLE 12
AMMONIA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of contained nitrogen)

Country	1992	1993	1994	1995	1996 e/
Afghanistan e/	40	30	30	30	30
Albania e/	15	15	15	15	15
Algeria	438	380	380	450 r/ e/	500
Argentina	72	72	73 r/	70 e/	70
Australia	392	398	413	433	433
Austria e/	410 r/	400	400	400	400
Bahrain	323	348	338	358	358
Bangladesh 3/	937	991	995 e/	975 e/	980
Belarus	916	619	500 e/	500 e/	500
Belgium	514	535	500 e/	500 e/	500
Bosnia and Herzegovina e/	5	2	1	1	1
Brazil e/	940	940	940	940	940
Bulgaria	905	885	800 e/	800 e/	800
Burma e/	110	110	130	130	130
Canada	3,104	3,410	3,470	3,773 r/	3,800
China e/	18,000	19,000	20,100 r/	22,600 r/	23,000
Colombia e/	86	99	90	90	90
Croatia	426 r/	345 r/	311 r/	295 r/	350
Cuba e/	135	135	130	130	130
Czech Republic e/ 4/	XX	149 5/	150	150	150
Czechoslovakia 6/	385 e/	XX	XX	XX	XX
Denmark e/	2	2 5/	2	2	2
Egypt	943	941	940 e/	940 e/	940
Estonia	115	45	45 e/	45 e/	50
Finland e/	10	10	12 r/ 5/	12 r/	12
France	1,848	1,871	1,480	1,470 r/	1,500

See footnotes at end of table.

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TABLE 12--Continued
AMMONIA: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of contained nitrogen)

Country	1992	1993	1994	1995	1996 e/
Germany	2,113	2,100	2,170	1,470 r/	1,200
Georgia	96	58	35 e/	30 e/	30
Greece	140	57	55 e/	55 e/	60
Hungary	152	237	230 e/	230 e/	250
Iceland	9	9 e/	9	9 e/	9
India 7/	7,452	7,176	7,334	7,713	7,800
Indonesia	2,688	2,888	2,800 e/	2,850 e/	2,870
Iran	664	723	696	700 e/	700
Iraq e/	200	500	500	500	500
Ireland	384	367	380 e/	370 e/	370
Israel 3/	37	41	41 e/	41 e/	41
Italy	1,100 e/	729	504	500 r/ e/	500
Japan	1,545 r/	1,471 r/	1,483 r/	1,584 r/	1,560
Kazakstan	220	231	200 e/	200 e/	200
Korea, North e/	550	600	600	600	600
Korea, Republic of e/	442 5/	450	460	470	475
Kuwait	140	320	325 e/	325 e/	325
Libya e/	200	200	200	200	200
Lithuania	275	275 e/	277	442	130
Malaysia	331	334	334 e/	340 e/	340
Mexico	2,203	1,758	2,030	1,992 r/	2,150
Netherlands	2,588	2,472	2,500 e/	2,500 e/	2,500
New Zealand	68	78	78 e/	80 e/	80
Nigeria e/	337 5/	350	350	350	350
Norway	343	315	270	275 r/	275
Pakistan	1,144	1,446	1,450 e/	1,450 e/	1,450
Peru e/	90	90	90	90	90
Poland	1,222 r/	1,163 r/	1,230 r/	1,415 r/	1,400
Portugal	100	91	100 e/	100 e/	100
Qatar	622	628	640	650 e/	650
Romania	1,421	1,328	--	1,000 r/ e/	1,000
Russia	8,786	8,138	7,500 e/	7,500 e/	7,000
Saudi Arabia	904	1,097	1,900	2,000 e/	2,000
Serbia and Montenegro	148	100	159	135 r/	135
Slovakia e/ 4/	XX	263 5/	250	250	250
South Africa	541	607	600 e/	600 e/	600
Spain	479	354	360 e/	360 e/	360
Switzerland	31	28	30 e/	30 e/	30
Syria	81	67	67	67 e/	68
Taiwan	224	220	215	226	220
Tajikistan e/	50	40	30	25	20
Trinidad and Tobago	1,568	1,462	1,649	1,696	1,801 5/
Turkey	344	326	350 e/	350 e/	350
Turkmenistan e/	50 r/	50 r/	50 r/	52 r/	48
Ukraine	3,908	3,242	3,000 r/ e/	3,100 r/ e/	3,000
United Arab Emirates	275	288	243	250 e/	250
United Kingdom	869	873	1,006	1,000 e/	1,000
United States 8/	13,400	12,600	13,400	13,000 r/	14,600 5/
Uzbekistan	1,309	1,105	1,100 e/	1,100 e/	1,100
Venezuela	404	535	505	600	605 5/
Vietnam e/	45	52 5/	53	52	53
Zambia e/	7	10 5/	10	10	10
Zimbabwe e/	67	70	70	70	70
Total	93,400 r/	91,700 r/	92,200 r/	96,100 r/	97,500

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 18, 1997.

3/ May include nitrogen content of urea.

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Reported figure.

6/ Dissolved Dec. 31, 1992.

7/ Data are for years beginning Apr. 1 of that stated.

8/ Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

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PEAT

By David E. Morse

Peat is a renewable, natural organic material of botanical origin and commercial significance. Peatlands are situated predominately in shallow wetlands areas of the Northern Hemisphere, where large deposits developed from the gradual decomposition of plant matter under anaerobic, or oxygen free, conditions. Peat has widespread use as a plant-growth medium in a variety of horticultural and agricultural applications, where its fibrous structure and porosity promote a unique combination of water-retention and drainage characteristics. Commercial applications include potting soils, lawn and garden soil amendments, and turf maintenance on golf courses. In industry, peat is used primarily as a filtration medium to remove toxic materials from mine and process waste streams, pathogens from sewage effluents, and deleterious materials suspended in municipal storm-drain water. In its dehydrated form, peat becomes hydrophobic and is a highly effective absorbent for fuel and oil spills on land and water.

The United States continued as a significant producer and consumer of peat for horticultural, agricultural, and industrial purposes. A variety of peat types was extracted and processed from more than 59 identified operations in 20 of the lower 48 States, and Alaska; varieties included, in order of importance, reed-sedge, sphagnum moss, humus, and hypnum moss. About 90% of U.S. peat production was from the Southeast and Great Lakes States; Florida, Michigan, and Minnesota ranked as the dominant producers. The United States imported about one-half of its total domestic peat requirements, principally from Canada, where deposits of sphagnum peat moss are extensive. A small amount of peat was exported.

Production

Peat production in the United States decreased 9.3% compared with 1995, according to the annual survey of domestic peat producers. This was in line with a long-term trend of declining U.S. peat production, a concomitant drop in the number of domestic operations, relatively flat domestic consumption, overall, and the capture of an important market share by Canadian sphagnum peat moss producers shipping to the United States. Domestic production data for peat production are developed from a voluntary survey of U.S. operations by the U.S. Geological Survey (USGS. Of the the 92 operations to which a survey request was sent, 51 responded, representing 95% of the total production shown in tables 1 and 2, and 34 were idle.

Geographically, domestic production was dominated by several operations in the Great Lakes region and the Southeast; the major producers were, in order of importance, Florida, Michigan, and Minnesota according to information reported to the USGS by the industry. About 56% of U.S. production was from operations in the Midwest, the Northeast, and the Western States. Reed-sedge peat accounted for about 77% of domestic production by weight. *(See tables 2, 3, and 4.)*

Consumption

Domestic peat sales volume in 1996 decreased to 640,000 metric tons, or 52% of total U.S. apparent domestic consumption. Packaged materials were 49% of total domestic sales tonnage and commanded premium prices. Canadian exports to the United States continued to supply about one-half of apparent domestic consumption.

About 90% of domestic peat was sold for use in general soil improvement, potting soils, and the nursery business, in order of importance. The remainder was used in a variety of applications, including seed inoculants, vegetable cultivation, mixed fertilizers, and packing for flowers and plants and in the industrial sector. *(See tables 3, 5, and 6.)*

Stocks

U.S. peat stocks fell by about 11%, to 340,000 tons, and represented nearly 100 days of consumption. Reed-sedge peat was 85% of total stocks. *(See table 4.)*

Prices

The total reported f.o.b. plant value of domestic peat sold in the United States was $18.5 million, according to the annual survey of peat producers. The total sales value of domestic peat increased compared with 1995 in spite of a decline in sales volume; the average unit value increased to $28.88 per ton, compared with $25.80 in 1995. On a unit-value basis, packaged sphagnum moss was valued at nearly $87 per ton, f.o.b plant; hypnum moss, $78 per ton; humus, $20 per ton; and, reed-sedge, $29 per ton. *(See tables 1, 3, 5, 7, and 8.)*

Foreign Trade

The United States continued to export minor tonnages of peat, which amounted to 19,000 tons, according to reports issued by the Bureau of the Census. U.S. peat exports were valued at $1.99 million, or about $104 per ton, f.a.s. *(See table 8.)*

Canadian sphagnum moss import volume of 665,000 tons in 1996 carried a customs value of $115 million, or $173 per ton. Imports from other countries were less than 2,000 tons.

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World Review

According to information available to the USGS, 23 countries were known to produce peat. Estimated production from countries in the former Soviet Union (FSU) account for a significant portion of global peat production, although a continuing decline was believed to be the result of political restructuring and unfavorable economic trends. Because the quantity of peat produced for agricultural purposes in the FSU is not reported on a consistent and reliable basis, worthwhile estimates cannot be made. The quantity of peat produced for agriculture in the FSU was, therefore, not estimated and is not included in world production tabulations, even though the quantity produced is thought to be significant. Peat production outside the FSU was dominated by Ireland, Finland, Germany, Sweden, and Canada, in order of importance. The remainder was produced principally by the United Kingdom and the United States, with minor contributions from countries in Europe, Latin America, and Oceania. *(See table 9.)*

Outlook

The outlook for horticulture and associated businesses is bright because global demand for various plants, flowers, ornamental trees, natural turf, and outdoor recreational activities continues to grow at impressive rates. The U.S. Department of Agriculture anticipates that the growth in monetary value for this industry in the United States will outpace that of traditional agriculture throughout the remainder of the decade. The outlook for the domestic peat industry, therefore, will likely be governed by several variables, including future wetlands environmental regulation, the ability to permit new bogs, growth and competition from recycled yard wastes and other natural organic materials, Canadian competition, and the degree of market penetration by flowers and ornamentals from offshore.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

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Peat. Ch. in United States Mineral Resources, U.S. Geological Survey Professional Paper 820, 1973.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT PEAT STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Number of active producers		71	67	70	64	59
Production	thousand metric tons	599	616	574	589 r/	549
Sales by producers	do.	652	612	552	660	640
Bulk	do.	288	343	255	339	325
Package	do.	365	268	297	320	314
Value of sales	thousands	$16,700	$16,800	$15,300	$17,000	$18,500
Average per metric ton		$25.70	$27.50	$27.20	$25.80	$28.90
Average per metric ton, bulk		$19.30	$19.60	$18.70	$22.50	$23.90
Average per metric ton, packaged or baled		$30.70	$37.70	$26.40	$29.20	$34.00
Exports	thousand metric tons	22	8	23	20 r/	19
Imports for consumption	do.	639	648	669	669	667
Consumption, apparent 2/	do.	1,230	1,290	1,240	1,110 r/	1,240
Stocks, December 31: Producers'	do.	308	269	252	384	342
World: Production	do.	29,300 r/	21,500 r/	24,700 r/	24,300 r/	25,800 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits; except prices.

2/ Apparent consumption equals U.S. primary production plus imports minus exports plus adjustments for industry stock changes.

TABLE 2
RELATIVE SIZE OF PEAT OPERATIONS IN THE UNITED STATES 1/

	Active operations		Production (thousand metric tons)	
Size in metric tons per year	1995	1996	1995	1996
23,000 and over	10	8	405	359
9,000 to 22,999	6	7	88	105
5,000 to 8,999	10	9	61	53
2,000 to 4,999	9	7	22	19
1,000 to 1,999	7	7	8	8
Under 1,000	22	21	5	5
Total	64	59	589 r/	549

r/ Revised.

1/ Data may not add to totals shown because of independent rounding.

TABLE 3
U.S. PEAT PRODUCTION AND SALES BY PRODUCERS IN 1996, BY STATE 1/

		Production	Sales		
Region and State	Active operations	Quantity (thousand metric tons)	Quantity (thousand metric tons)	Value 2/ (thousands)	Percent packaged
Northeast					
Pennsylvania	6	5	4	$166	7
Other 3/	7	40	40	1,600	88
Total	13	45	44	1,770	90
Great Lakes					
Michigan	9	171	168	4,650	92
Minnesota	7	19	20	1,540	56
Other 4/	12	64	69	4,250	92
Total	28	254	257	10,400	89
Southeast					
Florida	9	224	298	5,550	12
Other 5/	1	15	15	311	100
Total	10	239	313	5,860	15
West					
Washington	2	2	2	68	--
Other 6/	6	9	24	345	78
Total	8	11	26	413	38
Total or average	59	549	640	18,500	49

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Values for f.o.b. producing plant.

3/ Includes Maine, Massachusetts, New Jersey, New York, and West Virginia.

4/ Includes Illinois, Indiana, Ohio, and Wisconsin.

5/ Includes North Carolina and South Carolina.

6/ Includes Colorado, Iowa, Montana, and North Dakota.

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TABLE 4
U.S. PEAT PRODUCTION AND PRODUCERS' YEAREND STOCKS
IN 1996, BY KIND 1/

Kind	Active operations	Production (metric tons)	Percent of production	Yearend stocks (metric tons)
Sphagnum moss	11	46,500	8.5	18,500
Hypnum moss	7	29,400	5.4	1,220
Reed-sedge	28	423,000	76.9	291,000
Humus	16	50,400	9.2	32,200
Total	59 2/	549,000	100	342,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Number of active operations includes plants producing multiple kinds of peat.

TABLE 5
U.S. PEAT SALES BY PRODUCERS IN 1996, BY TYPE AND USE 1/

Use	Sphagnum moss			Hypnum moss			Reed-sedge		
	Quantity			Quantity			Quantity		
	Weight (metric tons)	Volume 2/ (cubic yards)	Value (thousands)	Weight (metric tons)	Volume (cubic yards)	Value (thousands)	Weight (metric tons)	Volume (cubic yards)	Value (thousands)
Earthworm culture medium	--	--	--	227	500	$4	1,200	2,640	$26
General soil improvement	24,400	130,000	$1,960	8,330	21,600	513	294,000	681,000	5,380
Golf courses	1,830	8,120	97	1,360	3,000	28	6,890	24,400	386
Ingredient for potting soils	1,940	9,220	106	10,500	24,100	198	162,000	362,000	3,040
Mixed fertilizers	--	--	--	--	--	--	22,700	50,000	475
Mushroom beds	--	--	--	--	--	--	--	--	--
Nurseries	16,100	95,900	1,210	1,160	4,570	44	29,800	87,200	887
Packing flowers, plants, shrubs, etc.	2,830	26,000	135	--	--	--	--	--	--
Seed inoculant	--	--	--	--	--	--	5,510	12,200	2,840
Vegetable growing	--	--	--	1,360	3,000	24	2,350	5,200	51
Other	1,830	8,140	97	--	--	--	--	--	--
Total	48,900	278,000	3,610	22,900	56,700	810	525,000	1,220,000	13,100

Use	Humus			Total		
	Quantity			Quantity		
	Weight (metric tons)	Volume (cubic yards)	Value (thousands)	Weight (metric tons)	Volume (cubic yards)	Value (thousands)
Earthworm culture medium	200	450	$6	1,630	3,590	$36
General soil improvement	14,600	23,900	292	342,000	856,000	8,150
Golf courses	1,330	3,100	45	11,400	38,600	556
Ingredient for potting soils	9,870	15,700	211	185,000	411,000	3,550
Mixed fertilizers	1,010	1,590	24	23,700	51,600	499
Mushroom beds	196	300	4	196	300	4
Nurseries	1,430	3,060	44	48,400	191,000	2,190
Packing flowers, plants, shrubs, etc.	272	500	3	3,100	26,500	138
Seed inoculant	--	--	--	5,510	12,200	2,840
Vegetable growing	1,150	2,530	31	4,860	10,700	105
Other	12,800	20,700	323	14,600	28,800	420
Total	42,900	71,900	982	640,000	1,630,000	18,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Volume of nearly all sphagnum moss was measured after compaction and packaging.

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TABLE 6
AVERAGE DENSITY OF DOMESTIC PEAT SOLD IN 1996 1/ 2/

(Kilograms per cubic meter)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus
Bulk	285	550	564	624
Package	205	475	558	827
Bulk and package	231	529	561	780

1/ Data are rounded to three significant digits.
2/ To convert kilograms per cubic meter to pounds per cubic yard multiply by 1.685.

TABLE 7
PRICES 1/ FOR PEAT IN 1996

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Average
Domestic:					
Bulk:					
Per metric ton	54.21	20.74	21.62	36.58	23.90
Per cubic yard	11.83	8.72	9.33	17.58	9.75
Packaged or baled:					
Per metric ton	86.53	78.36	28.68	19.68	34.02
Per cubic yard	13.54	28.44	12.24	12.45	12.86
Average:					
Per metric ton	73.66	35.34	24.91	22.89	28.88
Per cubic yard	12.99	14.29	10.69	13.66	11.34
Imported, total, per metric ton 2/	XX	XX	XX	XX	--

XX Not applicable.
1/ Prices are f.o.b. plant.
2/ Average customs value.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PEAT MOSS, 1/ 2/
BY COUNTRY

	1995		1996	
Country	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)
Canada	667,000	$121,000	666,000	$115,000
Denmark	17	9	362	90
Ireland	1,030	88	544	64
Other 4/	600 r/	284 r/	441	256
Total	669,000	121,000	667,000	116,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Poultry and fertilizer grade.
3/ Customs value.
4/ Includes Germany, the Netherlands, New Zealand, Norway, Sri Lanka, and the United Kingdom.

Source: Bureau of the Census.

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TABLE 9
PEAT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina: Agricultural use	1	3 r/	3 r/	4 r/	4
Australia e/ 4/	11	11	15	15	15
Belarus e/ 5/	350	350	348 6/	315 6/	279 6/
Burundi	12	10 e/	10	10 r/	10
Canada: Agricultural use	740	801	914	877 r/	783 p/
Denmark: Agricultural use (sales)	195	189	190 e/	190 e/	185
Estonia e/ 5/	1,000	1,000	1,274 6/	952 6/	950
Finland:					
Agricultural use	355	350 e/	550	500 e/	450
Fuel use	5,103	3,945	5,000 e/	5,000 e/	5,000
France: Agricultural use e/	200	200	200	200	200
Germany:					
Agricultural use	2,718	2,739	2,800 e/	2,800 e/	2,800
Fuel use	188	180	180 e/	180 e/	180
Hungary: Agricultural use e/	65	65	65	48 r/ 6/	45
Ireland:					
Agricultural use e/	300	300	250	300	300
Fuel use	5,414 r/	3,975 r/	4,696 r/	4,788 r/	7,087 6/
Latvia e/ 5/	300	300	647 6/	455 r/ 6/	463 6/
Lithuania e/ 5/	400	400	411 6/	214 6/	200
Netherlands e/	300	300	300	300	300
Norway: e/					
Agricultural use	30	30	30	30	30
Fuel use	1	1	1	1	1
Poland: Agricultural and fuel use	134	110 r/	109 r/	199 r/	200
Russia 5/	7,800	2,500	2,900	3,000 e/	2,500
Spain e/	70	70	70	70	70
Sweden: e/					
Agricultural use	260	250	250	250	250
Fuel use	1,400	1,400	1,400	1,400	1,400
Ukraine e/ 5/	1,000	1,000	1,000	1,000	1,000
United Kingdom e/	390	380	500	590	550
United States:					
Agricultural use	599	616	574	589 r/	549 6/
Fuel use	W	W	W	W	W
Grand total	29,300 r/	21,500 r/	24,700 r/	24,300 r/	25,800
Of which: Fuel use	12,100 r/	9,500 r/	11,300 r/	11,400 r/	13,700

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 25, 1997.

3/ In addition to the countries listed, Austria, Iceland, and Italy produced negligible amounts of fuel peat; Venezuela was a major producer, but output was not officially reported and available information was inadequate for formulation of estimates of output levels.

4/ Excludes data from some States.

5/ The majority of production appears to be for fuel use. This country also produced unreported quantities for agricultural use.

6/ Reported figure.

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PERLITE

By Wallace P. Bolen

The perlite industry ended 1996 with mixed results. The amount of processed perlite sold or used dropped about 2% compared with that of 1995, but the amount and value of expanded perlite sold or used in the United States again set records. Imports increased to 125,000 tons in 1996, while exports decreased slightly to 38,000 tons.

Production

The amount and value of U.S. processed perlite decreased slightly according to the U.S. Geological Survey (USGS). The amount of expanded perlite sold or used by domestic producers increased 2.7% to 670,000 metric tons, and the associated value increased nearly 8% compared with that of 1995. *(See table 1.)* Construction uses of expanded perlite, mostly formed products, accounted for almost 71% of total domestic sales in 1996.

Domestic production data for perlite are derived by the USGS from two voluntary annual surveys; one for domestic mine operations (processed perlite) and the other for expanding plants. All the processed perlite included in table 1 was produced by eight mines operated by six companies, all of whom responded to the survey request. Three companies reported three mines idle, bringing the total to eight companies with active or inactive perlite mines. Of the 69 expanding companies canvassed, 61 were active; 58 companies, or 84%, responded, reporting about 88% of the total expanded perlite sold or used shown in table 1. The perlite mined came from four Western States. New Mexico operations accounted for the vast majority of the total tonnage mined. Arizona, California, and Nevada accounted for the remaining tonnage. Ore producers were Harborlite Corp. in Arizona and New Mexico, American Perlite Co. in California, Wilkins Mining and Trucking Co. and Eagle-Picher Minerals Inc. in Nevada, and Dicaperl Corp. and USG Corp. in New Mexico. The top eight producers of expanded perlite, each with production of more than 25,000 tons annually, accounted for 86% of expanded perlite sold or used in the United States in 1996. The remaining 14% was sold or used by 25 companies.

Idaho Minerals (a subsidiary of Moneta Porcupine Mines, Inc. at Timmins, Ontario, Canada), which purchased the former Oglebay Norton Company mine, processing plant, and expanding plant located near Malad City, Idaho, in February, began operating in mid-1996. A small amount of perlite mined at the Wright Creek Mine was processed and expanded near Malad City. Some of the processed perlite was sold to other expanders.

Atlas Gold Corporation continued work on a mine and a processing facility at Tucker Hill, OR. A small amount of processed perlite, derived from a trial-scale run, has been delivered to an expander.

Pearlqueen Inc. is planning to open and operate a mine and a processing plant near Kaysville, UT.

The expanding facility opened by Harborlite Corporation in Youngsville, NC, in late 1995, was operational for all of 1996. The plant was opened in response to company studies that indicated a need for various grades of expanded perlite in the region. The only other producer in the region is Carolina Perlite Co., located in Gold Hill, NC.

Harborlite announced the closing of its Ft. Worth, TX, expanding plant. The plant was owned first by Nord Corp. and then by Filter Media Corp. After Harborlite bought out Filter Media, it decided to consolidate its Texas operations at the former Filter Media operation in LaPorte.

Perlite of Houston Inc. announced the permanent closure of its expanding plant near Tomball, TX. The company confirmed the closure was in response to increased competition and governmental regulations, and to raw material supply problems. The closure leaves idle two furnaces and related spare parts and equipment.

Innova Technologies closed its McQueeny, TX, expanding plant. The plant equipment was sold and the purchaser moved it to Monterrey, Mexico.

Consumption

Domestic apparent consumption is defined as U.S. processed perlite sold and used plus imports minus exports. In 1996, domestic apparent consumption of processed perlite was 771,000 metric tons, an increase of 3.6% from that of 1995. Consumption of expanded perlite for construction-related uses, the major market for expanded material, increased 6.3% to 475,000 tons. Expanded perlite used for filter aid, fillers, and agricultural applications decreased about 7% to 174,000 tons. Leading States, in descending order of expanded perlite sold and used, were Georgia, Mississippi, Illinois, Pennsylvania, Alabama, California, Florida, and Oregon. *(See tables 2 and 3.)*

Prices

Processed perlite sold at an average value of $28.14 per ton. Perlite consumed by expanding plants operated by the mining companies was valued by the mining companies at $28.50 per ton. The average price for all perlite sold or used by miners was $28.25 per ton. The average price of expanded perlite was $205 per ton; there was however, a wide range in quoted prices from less than $100 to more than $1,000 per ton.

The average prices for a ton of expanded perlite, by use, were miscellaneous uses, $512; low-temperature insulation,

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$444; fillers, $379; cavity-fill insulation, $356; filter aid, $315; horticultural aggregate, $310; concrete aggregate, $299; plaster aggregate, $220; and formed products, $139.

Foreign Trade

Exports of perlite, primarily to Canada, were estimated to be 38,000 tons. Imports of processed perlite, almost exclusively from Greece, increased to a record level of around 125,000 tons.

World Review

The United States was estimated to be the largest producer and consumer of crude and expanded perlite. Other leading countries, in descending order of production of processed (unexpanded) perlite, were Greece, Japan, Turkey, and Hungary. *(See table 4.)* Thirteen countries produced 1.68 million tons of processed perlite. Owing to a lack of reliable figures however, this total does not include several producing countries, including China, which is probably the largest or second largest producer in the world.

Outlook

Total consumption of expanded perlite and processed perlite in the United States is expected to increase in 1997. Moderate growth in imports of processed perlite are expected to slow the growth of domestic processed perlite sales. New mines and expanding plants throughout the United States should restrain price increases in many grades of processed and expanded perlite.

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TABLE 1
PERLITE MINED, PROCESSED, EXPANDED, AND SOLD AND USED BY PRODUCERS IN THE UNITED STATES 1/

(Thousand metric tons and thousand dollars)

		Processed perlite					Expanded perlite		
		Sold to expanders		Used at own plant to make expanded material				Sold and used	
Year	Perlite mined 2/	Quantity	Value	Quantity	Value	Total quantity sold and used	Quantity produced	Quantity	Value
1992	762	422	11,700	118	3,490	541	551	550	113,000
1993	691	453	13,800	116	3,680	569	566	562	111,000
1994	664	531	15,900	114	3,440	644	636	636	123,000
1995	813	592	16,200	108	3,350	700	657	652	127,000
1996	811	565	15,900	120	3,420	684	671	670	137,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Crude ore mined and stockpiled for processing.

TABLE 2
EXPANDED PERLITE PRODUCED AND SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

	1995				1996			
		Sold and used				Sold and used		
State	Quantity produced (metric tons)	Quantity (metric tons)	Value (thousands)	Average value per ton 2/	Quantity produced (metric tons)	Quantity (metric tons)	Value (thousands)	Average value per ton 2/
California	40,900	40,400	$10,200	$252	44,500	44,500	$12,100	$272
Florida	37,500	36,800	8,580	233	39,000	38,700	9,740	251
Michigan	31,600	31,600	6,050	191	27,700	27,700	5,720	207
Mississippi	81,500	81,500	8,400	103	69,500	69,500	7,390	106
Pennsylvania	51,900	51,900	9,610	185	49,300	49,300	9,060	184
Texas	16,600	16,100	4,710	292	9,540	9,540	3,610	378
Other 3/	397,000	394,000	79,100	200	431,000	430,000	89,700	208
Total	657,000	652,000	127,000	194	671,000	670,000	137,000	205

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Average value based on unrounded data and rounded to nearest dollar.
3/ Includes Alabama, Arizona, Arkansas (1995), Colorado, Georgia (1995), Illinois, Indiana, Kansas, Kentucky, Louisiana, Maine, Massachusetts (1995), Minnesota, Missouri, Nevada, New Jersey, North Carolina, Ohio, Oklahoma, Oregon, Tennessee, Utah, Virginia, Wisconsin, and Wyoming.

TABLE 3
EXPANDED PERLITE SOLD AND USED BY PRODUCERS
IN THE UNITED STATES, BY USE 1/

	1995		1996	
Use	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Concrete aggregate	4,790	$1,120	6,480	$1,940
Fillers	61,100	17,700	50,900	19,300
Filter aid	64,400	17,900	62,600	19,700
Formed products 2/	429,000	63,200	455,000	63,200
Horticultural aggregate 3/	62,000	18,600	60,700	18,800
Low-temperature insulation	2,270	1,220	2,070	920
Masonry and cavity-fill insulation	8,360	2,670	7,610	2,710
Plaster aggregate	5,230	1,130	5,720	1,260
Other 4/	14,900	4,230	18,700	9,570
Total	652,000	127,000	670,000	137,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes acoustic ceiling tile, pipe insulation, roof insulation board, and unspecified formed products.
3/ Includes fertilizer carriers.
4/ Includes high-temperature insulation, oil-water absorbents, acoustic tile, paint extender (1995), and various nonspecified industrial uses.

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TABLE 4
PERLITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Armenia e/	50,000	10,000	5,000	6,000	6,000
Australia e/ 4/	5,000	5,000	5,000	5,000	5,000
Czechoslovakia e/ 5/ 6/	50,000	XX	XX	XX	XX
Greece (screened)	398,360 r/	350,000 r/ e/	371,945 r/	360,000 r/ e/	350,000
Hungary 4/	93,000 e/	80,000	85,000	104,000	105,000
Iran e/	5,000	6,000	6,000	6,000	6,000
Italy e/	65,000	65,000	65,000	60,000	60,000
Japan e/	203,000	200,000	200,000	200,000	200,000
Mexico 4/	42,637	34,600 e/	31,918 r/	29,471 r/	30,000
Philippines e/	2,800	19,779 7/	20,000	20,000	20,000
Slovakia e/ 6/	XX	50,000	50,000	50,000	50,000
South Africa	97	328	914 r/	1,338 r/	1,300
Turkey 4/	280,883	147,864	164,582	165,000 e/	160,000
United States (processed ore sold and used by producers)	541,000	569,000	644,000	700,000	684,000 7/
Total	1,740,000 r/	1,540,000 r/	1,650,000 r/	1,710,000 r/	1,680,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Unless otherwise stated, figures represent processed ore output. Table contains data available through May 20, 1997.

3/ In addition to the countries listed, Algeria, Bulgaria, China, Iceland, Mozambique, and the former Yugoslavia are believed to have produced perlite, but output data are not reported, and available information is inadequate for the formulation of reliable estimates of output levels.

4/ Crude ore.

5/ Dissolved on Dec. 31, 1992.

6/ All production for Czechoslovakia in 1992 came from Slovakia.

7/ Reported figure.

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PHOSPHATE ROCK

By Joyce A. Ober

Phosphorus is an essential element for plant and animal nutrition. Most phosphorus is consumed as a principal component of nitrogen-phosphorus-potassium (NPK) fertilizers used on food crops throughout the world. Phosphate rock minerals are the only significant global resources of phosphorus.

The United States is the world's leading producer and consumer of phosphate rock, which is used to manufacture phosphate fertilizers and industrial products for domestic use and export. In 1996, 10 companies operated 18 phosphate rock mines. More than 90% of the phosphate rock mined was used to produce chemical fertilizers, and in 1996, production increased for the third consecutive year. Companies in Florida and North Carolina produced about 86% of the marketable phosphate rock mined in the United States and processed most of the refined mineral in fertilizer upgrading facilities. The average value of marketable phosphate rock increased by 8% from that of 1995.

Phosphate rock also is produced in the Western States of Idaho and Utah where the mineral was upgraded into high-analysis phosphate fertilizers and elemental phosphorus (P_4), which is used to produce downstream industrial products. Idaho and Montana produced most of the P_4 consumed domestically and exported from the United States.

In the United States, marketable phosphate rock production and consumption each increased by about 4%. U.S. phosphate rock sold or used by producers was 43.5 million metric tons, which is equivalent to 85% of effective industry capacity. *(See tables 1 and 2.)* The U.S. Department of Commerce reports that wet-process phosphoric acid (WPPA) production was 11.9 million tons as available phosphorus pentoxide (P_2O_5), which represented an industry operating rate of nearly 100% (U.S. Department of Commerce, 1997). The United States accounted for more than 55% of global interregional converted phosphate P_2O_5 trade in order of importance—ammonium phosphates [diammonium phosphate (DAP) and monoammonium phosphate (MAP)], granular triple superphosphate (TSP), and WPPA.

Legislation and Government Programs

The Federal Agriculture and Improvement Reform (FAIR) Act, Public Law 104-127, also known as the Freedom to Farm Act, was passed into law and signed by the President of the United States on April 4, 1996. Because the phosphate rock industry is so heavily dependent on the production and sales of phosphate fertilizers, any changes in U.S. farm legislation are watched closely by phosphate producers. The law contains nine sections, but the major provisions that have the greatest potential impacts for the fertilizer industry can be summarized briefly. The most pertinent portions of the law are Title I—Agricultural Market Transition Act and Title III—Conservation.

Title I.—This portion of the new law changes the way income-support payments to farmers are determined. In the past, these deficiency payments were based on the difference between actual market prices and target prices during a specific time period or the price-support loan rates, whichever were higher. FAIR eliminates the link between market prices and income-support payments, and payments are based on the number of acres covered by income support contracts and a predetermined per-unit payment rate now determined annually by the U.S. Department of Agriculture (USDA). Total contract payments are set for each year specified in the plan and will decrease annually for the following 7 years, which is the period covered under FAIR; payment caps for individual farmers were reduced from $50,000 per person to $40,000 per person. Coupled with the changes to the way deficiency payments are determined is the new flexibility that allows farmers to plant contract acreage with any crop of their choosing, except fruits and vegetables; in the past, farmers could only plant the crop specified in the contract to receive payment. This provision could affect the fertilizer industry because different crops have different nutrient requirements, which would possibly alter the patterns of fertilizer applications throughout the country. Acreage Reduction Programs, which limited the number of acres that contract participants could plant with a specified crop, were eliminated. Opinions on how or if these changes will affect the consumption of phosphate fertilizers are mixed; much depends on what crops are actually planted. For the most part, phosphate producers expect positive growth, but it may take several years under the program to define new consumption patterns.

Title III.—Changes to the conservation provisions of 1990 Farm Bill are also expected to affect the phosphate industry. Previous farm legislation had allowed annual rental payments to farmers who entered a contract to withhold voluntarily environmentally sensitive land from agricultural production under the Conservation Reserve Program (CRP). The number of hectares that could be enrolled in CRP was limited to 15.4 million. FAIR reduced the cap to 14.7 million hectares and allowed for CRP land that meets USDA requirements to be withdrawn from CRP and to be enrolled in production flexibility contracts. New acreage could be enrolled in CRP, but the criteria were more stringent. At a minimum, Title III will return 650,000 hectares to production; increased acreage, however, may be much more, perhaps as much as one-half of CRP hectares (Green Markets, 1996e). This would have a positive

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impact on the fertilizer industry. Any acreage returned to production would require additional fertilizer inputs, increasing fertilizer consumption and benefiting the phosphate industry.

Production

Consolidation of the fertilizer industry that began in 1995 continued in 1996. In March, IMC Global Co. merged with Vigoro Corp. IMC Global, which manufactures potash and phosphate, acquired Vigoro's potash and nitrogen businesses, as well as a retail business. In September, Potash Corp. of Saskatchewan (PCS) announced plans to acquire Arcadian Corp., a nitrogen producer. This acquisition would make PCS a producer of all three major fertilizer elements—potassium, phosphorus, and nitrogen. The shareholders' final vote on the merger was scheduled for January 1997. In December, Canadian producer Agrium Inc. acquired Viridian Inc. for an estimated $887 million. Although Agrium already produced all three fertilizer nutrients, it increased its nitrogen production by acquiring Viridian (Kirschner, 1997).

Southern States.—In Florida, phosphate rock was mined and processed by six producers—Cargill Fertilizer, Inc.; CF Industries, Inc.; IMC-Agrico Co.; Mobil Mining and Minerals Corp.; PCS; and U.S. Agri-Chemicals Corp. Their mines and plants were located in Hamilton, Hardee, Hillsborough, and Polk Counties. Nu-Gulf Industries' Wingate Creek Mine and the associated Mulberry Phosphates Inc., Piney Point ammonium phosphate conversion plant in Manatee County were idle. Farmland Industries, Inc.-Norsk Hydro, L.P., and Mulberry Phosphates operated WPPA and ammonium phosphate plants at Green Bay and Bartow, respectively, using phosphate rock purchased domestically as feed.

In January, Mobil Mining and Minerals sold its South Fort Meade, FL, mining operations to Cargill Fertilizer Inc. for $283 million. The beneficiation plant at the operation was designed to process 3.6 million tons per year of rock; rock reserves were estimated to be 104 million tons. Mobil also announced plans to sell its Nichols Mine to Nichols Phosphate Acquisitions Corp. (NPAC); NPAC's name was changed later to Agrifos L.L.C. The acquisition also included about 4,000 hectares of phosphate reserves in Polk County and a phosphate rock processing and drying plant and related equipment. Rock production capacity at the mine was estimated to be 1.36 million tons per year. NPAC agreed to a long-term tolling arrangement with Mobil to upgrade Nichols rock to DAP and MAP (Green Markets, 1996n). As a result of Mobil's exit from the phosphate rock market, PhosRock, the association established in 1970 to market phosphate rock overseas for U.S. producers, officially was dissolved on January 1, 1996.

Increased DAP inventories and seasonal downturns led IMC-Agrico to reduce production or close temporarily some of its DAP plants. Its 900,000-ton-per-year DAP plant in Taft, LA, was temporarily shut down between March 11 and July 22, when IMC-Agrico entered into a sales arrangement to ship 150,000 tons of DAP to China during the second half of 1996 (Green Markets, 1996l). The Taft plant was reidled on September 27 because of a drop in domestic phosphate demand (Green Markets, 1996k). The company also ran its New Wales, FL, facility at 80% of its 2.7-million-ton-per-year capacity from April 18 to July 1, when it resumed full production capacity. The Nichols DAP plant, with an annual capacity of 545,000 tons, was shut down temporarily on May 14; at yearend, the plant remained idle (Green Markets, 1996h).

IMC-Agrico announced that it will end phosphate rock supply contracts with overseas customers when the current contracts expire in July 1997. The company, which has been using its own production to supply rock needs at its chemical operations, is sensitive to finite reserves and wants to limit sales to the merchant market to ensure adequate internal supplies (Green Markets, 1996m).

U.S. Agri-Chemicals, a subsidiary of China's Sinochem, completed a 450,000-ton-per-year MAP powder plant in Ft. Meade, which will enable it to use all the phosphoric acid it produces. The powdered MAP will be sent to Sinochem Fertilizer Co. Ltd.'s Nanjang, China, facility where it will be converted to NPK fertilizers. U.S. Agri-Chemicals had been selling its excess phosphoric acid to Cargill Fertilizer's plant in Bartow, where it was converted to DAP (Green Markets, 1996u).

IMC-Agrico purchased 9,700 hectares of land from Consolidated Minerals Inc. for approximately $31 million. This land in southeastern Manatee County and northwestern DeSoto County is estimated to contain about 91 million tons of phosphate rock reserves, averaging 67% bone phosphate of lime. The purchase brings IMC-Agrico's Florida phosphate rock reserves to about 450 million tons (Green Markets, 1996g).

Rhône-Poulenc S.A. invested about $2 million to upgrade its high-purity phosphoric acid plant near Nashville, TN. With the investment, the company plans to produce an ultrapure phosphoric acid to meet semiconductor standards (North American Mineral News, 1996).

Western States.—In Utah, Simplot-Farmland Phosphates Ltd. Co., a joint venture between J. R. Simplot and Farmland Industries, Inc., operated a major mining and phosphate rock benefication facility at Vernal, which supplied its phosphate fertilizer production plant at Rock Springs, WY.

In Idaho, five firms mined or processed phosphate rock, either for the production of P_4 in electric furnaces for industrial applications or for conversion to WPPA and finished phosphate fertilizers. Three producers conducted open pit mining from the Phosphoria Formation in Caribou County, producing phosphate rock as feedstock for P_4 furnaces. FMC Corp. operated the Dry Valley Mine, Caribou County, on Federal and private leases to provide feedstock for P_4 production at Pocatello. The Monsanto Co. produced phosphate rock from the Enoch Valley Mine in the Caribou National Forest for P_4 production at Soda Springs. Rhône-Poulenc Basic Chemicals Co. produced phosphate rock from the Rasmussen Ridge Mine in the Caribou National Forest for P_4 manufacture at Silver Bow, MT, and domestic sales.

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Environment

Mulberry Phosphates received consent orders proposed by the Florida Department of Environmental Protection covering the firm's phosphogypsum stacks at Mulberry and Piney Point. At yearend, the company also was finalizing plans to restart production at its DAP plant in Piney Point by late 1997; the plant has been closed since 1992. Production of 500,000 tons per year of DAP is expected when the plant reopens. Rock for the plant will be supplied by Mulberry's Wingate Creek Mine, which will be reopened about 1 month before the DAP plant. Mulberry signed a letter of intent with Monsanto Envirochem to refurbish the sulfuric acid plant that will be needed to feed the DAP operation. Estimated cost for the restart is $35 million (Fertilizer Week, 1996d).

In response to a petition from The Fertilizer Institute, the U.S. Environmental Protection Agency (EPA) reconsidered a June 3, 1992, final rule revising the National Emission Standard for Radon Emissions from Phosphogypsum Stacks. The EPA proposed a rule to amend research and development regulations that would make it easier for researchers to use phosphogypsum in laboratory and field test settings and to change the methodology used to establish average radium-226 concentrations for a phosphogypsum stack. After a hearing on August 1, the comment period on the proposed regulations was extended to August 31 (U.S. Environmental Protection Agency, 1996).

Consumption

In 1996, U.S. apparent domestic consumption of phosphate rock increased by about 3% compared with that of 1995. About 94% of the total was consumed in the manufacture of 11.9 million tons P_2O_5 WPPA for downstream fertilizer, animal feed derivatives, and purified WPPA for industrial applications. The balance was used to produce P_4 for industrial applications, including detergent and food additives, water- and metal-treatment chemicals, plasticizers, pesticides, vitamins, soft drinks, toothpaste, photographic film, light bulbs, bone china, flame-resistant fabrics, optical glass, and other consumer goods. *(See tables 3 and 4.)*

Stocks

Although producers' yearend stocks increased about 12% from the 1995 level, they remained equivalent to almost 2 months of production, the same production level as that of 1995.

Transportation

In Florida, beneficiated phosphate rock was moved by rail and truck to phosphate upgrading facilities. Phosphate rock and finished phosphate materials were railed to ports at Tampa and Jacksonville, and then were shipped elsewhere for domestic use or exported. Finished phosphate fertilizers and phosphate rock were barged north on the Mississippi River and other major tributaries for domestic consumption and were also transported inland by rail and truck.

In North Carolina, PCS barged phosphate rock and finished products to the port at Morehead City for export and domestic shipment. Rail facilities also were utilized extensively for transport.

Western producers moved phosphate rock from mines to plants by rail, truck, and slurry pipeline. Finished product was moved predominately by rail and truck.

Prices

The weighted average value for marketable phosphate rock in 1996 was $23.40 per ton, f.o.b. mine. This was an increase of almost 8% from the 1995 value. *(See table 5.)*

Foreign Trade

Exports of phosphate rock decreased by 47% from the 1995 level primarily because of IMC-Agrico's decision to stop exporting the material. About 77% of rock exports was shipped to Asia (India, Japan, and the Republic of Korea), and 13% was shipped to Oceania (Australia and New Zealand).

The United States was the third largest importer of phosphate rock from Morocco, with nearly 1.7 million tons in 1996, a decrease from that in 1995. Arcadian and Mississippi Phosphates Corp. used Moroccan phosphate rock in phosphate conversion plants at Geismar, LA, on the Mississippi River, and at Pascagoula, MS, on the U.S. Gulf Coast. Arcadian also used imported ore as feedstock for a purified industrial-grade WPPA plant at Geismar that it operates on behalf of Rhône-Poulenc.

U.S. converted phosphate trade in 1996 appeared to show a significant decrease because of a drop in exports of DAP, particularly to China and India. These DAP exports are believed to be understated and are being investigated by the Bureau of the Census. According to data from the International Fertilizer Industry Association, 1996 U.S. DAP export shipments were 76% of the global total; MAP, 90%; TSP, 48%; and merchant-grade WPPA, 11%. *(See tables 6, 7, 8, 9, 10, 11, and 12.)*

World Review

World phosphate rock production was about 133 million tons in 1996, a slight increase compared with that of 1995. Phosphate rock was produced in about 40 countries; the United States was the largest, with about 34% of total production, followed by China, Morocco, and Russia.

Production in the Middle East was at 98% of total capacity, the highest utilization rate of any geographic region. Capacity utilization in the United States was 89%; Latin America, 85%; Asia, 81%; Africa, 78%; and Europe and Oceania, less than 50% each. *(See tables 13 and 14.)*

Australia.—WMC Fertilizers Ltd., a subsidiary of Western Mining Corp., plans to mine a phosphate deposit in Queensland

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and to upgrade the mined rock into 1 million tons per year of DAP and MAP. Reserves at the Phosphate Hill deposit were reported to contain 2 billion tons of phosphate rock, with mining reserves of 103 million tons; average grade of the rock is 23% P_2O_5. The company also plans to construct a new sulfuric acid plant, an ammonia plant, a phosphoric acid plant, and a granulation plant. Plant construction is expected to begin by the third quarter of 1997, with fertilizer production to begin in 1999. Most of the output will be used locally; some will be exported to Southeast Asia (Green Markets, 1996v). An initial production level of 750,000 tons per year of DAP/MAP is expected.

Brazil.—Since the Government privatized the fertilizer products industry in the early 1990's, production of almost all fertilizer products has been controlled by a small number of companies. Several acquisitions in 1996 reinforced this control. Serrana S.A. reportedly purchased 51% of Fertisul, a fertilizer producer, for an estimated $22 million. Serrana and Fertisul already operate two companies—Arafertil and Ipiranga-Serrana—through 50-50 joint ownership; Serrana will assume full control of these operations. Arafertil has an annual capacity of 800,000 tons of phosphate rock and 750,000 tons of single superphosphate (SSP). Ipiranga-Serrana has a 1.2-million-ton-per-year capacity to produce blended fertilizers. After the acquisition, Serrana will have control of 30% of Brazil's phosphate rock production, 20% of its phosphoric acid production, 20% of its MAP production, 15% of its SSP/TSP production, and 10% of its blended fertilizer production (Fertilizer Markets, 1996f). Two companies in the Fertifos Group—Fertiza and Fertibras—purchased Adubos Trevo AS's SSP/TSP plant in Cubatao, Sao Paulo, for $8 million. The plant, which has an annual capacity of 130,000 tons of SSP/TSP, also can granulate 650 tons per day of product. This purchase will enable Fertiza and Fertibras to expand production. The Cubatao plant had been closed since 1995 because of Adubos Trevo's financial difficulties (Fertilizer Markets, 1996a).

The Fertifos Group announced plans to invest $80 million to expand capacity at its Fosfertil and Ultrafertil subsidiaries. A 200,000-ton per-year P_2O_5 phosphoric acid plant and a 500,000-ton-per-year sulfuric acid plant will be constructed at Fosfertil's Uberaba, Minas Gerais, complex by the second half of 1997. Estimated cost for these plants is $55 million. The phosphoric acid plant is scheduled to be run initially at 40% of capacity; capacity would be increased depending on market conditions. Phosphoric acid will feed Fosfertil's MAP/TSP granulation complex, which has been operating at 80% of its 1-million-ton-per-year capacity because of short phosphoric acid supply. The additional MAP/TSP produced is targeted for competition with imported material in the domestic market (Fertilizer Markets, 1996b).

Canada.—In October, Agrium and Viridian agreed to merge in a stock exchange deal, creating a company worth about $2 billion. The merger will require regulatory approval by the United States and Canada before it is finalized. Each of the two companies is estimated to have a 25% share of the fertilizer market in western Canada, and Viridian is estimated to have a less-than 5% share of the U.S. market. Both firms have ammonia and urea production facilities in Canada, Agrium has a 499,000-ton-per-year DAP facility, and Viridian operates a 300,000-ton-per-year phosphoric acid plant (Fertilizer Week, 1996a).

Earth Sciences Inc. expects to begin producing purified phosphates at a new 16,300-ton-per-year plant in Calgary, Alberta, by early 1997. The permits to build and operate the facility have been received, and the company is negotiating to purchase 11,800 tons per year P_2O_5 of super phosphoric acid to upgrade. The purified product will be made into 75% white acid for industrial uses (Green Markets, 1996b).

China.—IMC-Agrico announced that it signed an exclusive letter of intent with the Yunnan Phosphorus Chemical Industry (Group) Corp. and the Yunnan Provincial Petroleum & Chemical Industry Bureau to study phosphate ore resources in the Yunnan Province. If commercially feasible, IMC-Agrico and the Chinese concerns plan to develop the deposits jointly (Green Markets, 1996i).

The Yunnan Phosphate Fertilizer Industrial Co. began operations at a new 140,000-ton-per-year P_2O_5 phosphoric acid plant and a 400,000-ton-per-year TSP plant in Kunming, Yunnan Province, in the third quarter of 1996. The phosphoric acid plant uses a two-stage thermal acid process with elemental phosphorus produced in the first stage and phosphoric acid independently produced in the second stage. The TSP plant uses the slurry process to produce a 46% P_2O_5 product (Phosphorus & Potassium, 1996d).

The Canadian firm Spur Ventures Inc. reportedly signed a preliminary agreement with Yuanyi Phosphorus Chemical Industries Group Co. to develop a phosphate rock deposit in Hubei Province. The Yichang deposit reported proven and probable reserves of 396 million tons, with an average P_2O_5 content of 23%. Preliminary plans are to mine 2.5 million tons per year of rock and to construct a 500,000-ton-per-year DAP plant near Yichang City. Capital costs for the mining operation were estimated to be $138 million, and capital costs for the DAP plant were estimated to be $260 million. Spur estimated operating costs to be $12 per ton for mining and $130 per ton for DAP production. All the production was targeted for the Chinese market (Green Markets, 1996a).

In December, IMC-Agrico reported that it reached a new 2-year DAP supply contract with Sinochem that covers the 1997 and 1998 calendar years. Shipment volumes for the 2 years will be approximately the same as those in 1996, and monthly shipments will reflect market prices at the time of shipment. This is the first contract of this time length for U.S. exports (Green Markets, 1996j).

India.—One of the largest DAP producers in India, Godavari Fertilisers and Chemicals Ltd., announced that it would switch from production of DAP to complex fertilizers principally because high prices of DAP in India have led to large inventories. The company had been in the process of increasing DAP capacity from 300,000 tons per year to 450,000 tons per year; this increase will be used for complex fertilizer

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production instead (Green Markets, 1996f).

The Spanish firm Incro S.A. was awarded a contract to upgrade Fertilisers & Chemicals Travancore Ltd.'s DAP/NPK plant in Cochin. The upgrading was expected to increase annual capacity to 400,000 to 450,000 tons. Startup was scheduled for 1997 (Green Markets, 1996d).

Indonesia.—PT Istana Kanematsu opened a new phosphate fertilizer plant in Ciamis, West Java, in October. The new plant, which will supply fertilizers for peat farming lands, has an annual capacity of between 600,000 and 720,000 tons of ground phosphate rock and SSP. Cost of the plant was estimated to be $55 million. PT Istana Kanematsu is a joint-venture company owned by PT Elang Istanamas of Indonesia (60%) and Kanematsu Corp. of Japan (40%) (Fertilizer Week, 1996c).

Kazakstan.—In July, the U.S. trading company IBE Trade Corp. acquired management control over the Kara Tau phosphate complex with a 51% control of the shares of the complex. IBE has an option to purchase the shares after 10 years. The complex includes five phosphate rock mines, the Dzambul Superphosphate Works, and Nadphos, which is the phosphate producer in Novodzambul. IBE reportedly offered $92 million in investments over several years to improve the complex. The first phase would include replacing equipment, roads, and mills at the five phosphate rock mines. The second phase would include the construction of a new WPPA plant at the MAP/DAP facility.

Although the Kara Tau mines were shut down through most of 1995 because of lack of financing, they had been expected to produce up to 2.4 million tons of rock in the second half of 1996. Most of this rock is exported to Uzbekistan, and the MAP produced at the complex is shipped to China (Fertilizer Markets, 1996c). By the end of October, IBE had invested $23.6 million in the complex, and the complex produced more than 2 million tons of phosphate rock. Work to upgrade the Dzanbul superphosphate plant from an annual capacity of 180,000 tons of 42% P_2O_5 MAP to 300,000 tons of 46% P_2O_5 MAP was planned to begin in December (Fertilizer Week, 1996b).

Morocco.—Office Cherifien des Phosphates (OCP) reported exports of phosphate rock to be 10.1 million tons in 1996. Spain (18%), Mexico (17%), and the United States (17%) were the principal destinations.

OCP plans to invest $1.06 billion within 5 years to expand its operations. Expansions include phosphate rock and phosphate fertilizer production. Phosphate rock production will increase by 5 million tons per year to 25 million tons per year, of which 14 million tons per year is earmarked for domestic consumption. Annual phosphoric acid production is expected to increase from 2.6 to 3.2 million tons at the Safi and the Jorf Lasfar complexes. The construction of two new phosphoric acid plants at Jorf Lasfar by 2000 was planned in joint ventures with foreign partners; each plant has been designed to produce 1,000 tons per day (Green Markets, 1996p).

Construction of a new 120,000-ton-per-year phosphoric acid plant in Jorf Lasfar was agreed to at the end of February. The new plant, called Euro Maroc Phosphore (Emaphos) is a 50-50 joint venture between OCP and Belgium's Société Chimique Prayon-Rupel S.A.; construction is estimated to cost $50 million. Production is scheduled to begin in July 1997 (Green Markets, 1996c).

In November, OCP announced that it had obtained $12.8 million financing to construct a purified phosphoric acid plant about 200 kilometers south of Rabat. The project is a joint venture with the Belgian firm Recticel, and acid production for the industrial market is expected to begin in July 1997 (Fertilizer Markets, 1996d).

OCP entered into a 6-year agreement to supply France's Grande Paroisse with 600,000 tons per year of phosphate rock beginning on January 1, 1997. The rock will go toward production of phosphoric acid, and much of the acid produced will be returned to OCP (Green Markets, 1996r).

Pakistan.—Morocco's OCP entered into an agreement with Al Noor Fertilizer Industries Ltd. to build a $220 million fertilizer plant in the Sindh Province. Annual production capacity at the new plant will be 1,300 tons per day of DAP, 1,200 tons per day of urea, and 955 tons per day of ammonia. OCP will supply all the plant's phosphoric acid needs from Morocco. Scheduled startup for the operation is in early 1998 (Green Markets, 1996q).

Peru.—As part of its privatization, Peru's state mining company, Minero Peru, planned to sell its Bayovar phosphate deposits on February 11, 1997. The Bayovar deposits have estimated phosphate reserves of 262 million tons. At least 12 companies have expressed interest in the property. The eventual buyer will have 3.5 years to develop the deposits (Green Markets, 1996o).

Philippines.—The Philippine Government, which owns 50.01% of the Philippine Phosphate Fertilizer Corp. (Philphos), proposed a plan to foreclose on Philphos' assets and to form a new company that would be fully owned by the Government. This plan is opposed by the Government of Nauru, which owns the remaining 49.99% of Philphos. Although Philphos has some operating profits from 1995, the profits have been used to pay interest charges, and the company remains in debt as a result of peso depreciation, yen appreciation, and construction costs from the early 1980's. Although Philphos supplies 70% of the Philippines growing fertilizer needs, no decision on its fate had been reached by yearend (Phosphorus & Potassium, 1996a).

Russia.—Because of low demand from Former Soviet Union (FSU) phosphate producers, Apatit, Russia's largest phosphate rock producer, announced that it would close one of its two beneficiation plants on the Kola Peninsula on July 1, 1996, for an indefinite period. The two beneficiation plants were operating well below the combined 12-million-ton annual capacity before the closure, and energy costs in the region made operating the second plant at 50% of capacity prohibitive. Apatit also ended rock deliveries to some FSU MAP and DAP producers because of nonpayment for first half 1996 deliveries. Because Apatit intended to increase exports of phosphate rock to Norway, Finland, and Germany in 1997, it was dredging the Murmansk port to allow panamax vessels to operate (Fertilizer Markets, 1996e).

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Saudi Arabia.—Sabic plans to construct an acids complex in Jubail. The complex will produce 250,000 tons per year of phosphoric acid, as well as sulfuric acid and aluminum fluoride. Plant construction was scheduled to begin in 1997, and was expected to be completed by 1999 (Green Markets, 1996s).

Senegal.—In September, Compagnie Sénégalese Des Phosphate de Taïba announced plans to merge with Industries Chimiques de Sénégal (ICS), its principal customer; the merger will be retroactive to January 1, 1996. The Senegalese Government would have 25% to 30% ownership in the new company, compared with the current ownership of 50% in Taïba and 37.5% in ICS. Taïba produces 1.5 million tons per year of phosphate rock, of which about 1 million tons per year is exported. The remainder is shipped to ICS' 385,000-ton-per-year P_2O_5 phosphoric acid plant. After the merger, the new company plans to increase annual mine production capacity to about 3 million tons, which would support a doubling of phosphoric acid production capacity (Phosphorus & Potassium, 1996b).

Togo.—The Togolese Government announced plans to sell 40% of its holdings in Office Togolais de Phosphates (OTP), the country's only producer of phosphate rock. A committee from the World Bank was assessing OTP's asset value, and an offer for the sale is expected to be made in March 1997. Production capacity at OTP's mine is estimated to be 3.4 million tons per year of rock, and all of the production is exported (Phosphorus & Potassium, 1996c).

Vietnam.—Japan's Tomen Corp. reportedly plans to build a 330,000-ton-per-year phosphate plant near Hanoi. The $180 million plant would be fed by domestic phosphate rock deposits and would be built as a joint venture with the Vietnam National Chemical Corp. (Green Markets, 1996t).

Outlook

U.S. and world annual capacity to mine and beneficiate phosphate ore into marketable phosphate rock continued to exceed domestic and world demand by an estimated 11% and 19%, respectively, in 1996. U.S. phosphoric acid output was very near usable capacity, and world phosphoric acid production was about 94% of available capacity. Fertilizer consumption and plant operating rates in the countries of the FSU remained well below the levels reported prior to the dissolution of the U.S.S.R.

Demand for phosphate rock in the United States is driven primarily by the fertilizer sector, which supplies North America's needs and is the major supplier to world markets; more than one-half the P_2O_5 in finished fertilizers manufactured in the United States is contained in exported materials. With the changes in U.S. farm policy and "Freedom to Farm," the expectation is that more acres will come into production beginning in 1997; the increase in area, however, is relatively small compared to the total. If export sales are maintained, then the expectation is that the U.S. phosphate industry should have results very similar to those of 1996 (that is, phosphate rock production and consumption of about 45 million tons and P_2O_5 in fertilizer sales in the United States of about 4.5 million tons and in exports of finished products of 5.2 million tons) through the remainder of the century. Exports of phosphate rock are expected to decline again in 1997, and the United States will be a net importer as long as the contracts for rock imports from Morocco remain in force.

On a global basis, new mining operations will probably come on-stream in the next 5 years in Australia and Saudi Arabia and possibly in China and Bolivia. An expansion in Morocco is also probable. The biggest mining question remaining is the future of operations on the Kola Peninsula in Russia and operations in Kazakstan, which continue to operate well below the output levels of the late 1980's. Some new fertilizer production capacity will probably be added in Africa, the Middle East, and Southeast Asia. Future fertilizer plant capacity utilization in the countries of the FSU is very uncertain.

Because of the nutritional needs of an expanding population, world fertilizer demand should also increase. The expectation is that world phosphate demand will grow by an estimated 1.2% to 1.5% annually through 2000. If many of the areas being farmed today received fertilizers for proper crop nutrition, then demand would increase substantially and the increased yields would allow a reduction in total acres planted.

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TABLE 1
SALIENT PHOSPHATE ROCK STATISTICS 1/

(Thousand metric tons and thousand dollars unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Mine production (crude ore)	155,000	107,000	157,000	165,000	179,000
Marketable production	47,000	35,500	41,100	43,500	45,400
P2O5 content	14,100	10,700	12,100	12,800	13,300
Value	$1,060,000	$759,000	$869,000	$947,000	$1,060,000
Average per metric ton 2/	$22.53	$21.38	$21.14	$21.75	$23.40
Sold or used by producers 3/	45,100	40,100	43,900	43,700	43,500
P2O5 content	13,500	11,900	13,100	13,000	12,900
Value 4/	$1,020,000	$856,000	$929,000	$950,000	$1,020,000
Average, dollars per metric ton	$22.53	$21.38	$21.14	$21.75	$23.40
Exports 5/	3,720	3,200	2,800	2,990	1,570 6/
P2O5 content	1,200	1,020	886	875	NA
Value	$120,000	$91,200	$71,700	$78,300	NA
Average, dollars per metric ton	$32.29	$28.51	$25.60	$28.35	$35.82
Imports for consumption	1,530	534	620 7/	1,080 e/ 7/	1,800 e/ 7/
C.i.f. value	$56,200	$32,300	$30,200	$55,200 e/	$104,000 e/
Average, dollars per metric ton	$36.71	$60.45	$48.76	$51.01	$57.91
Consumption 8/	42,900	38,300	42,900 e/	42,000 e/	43,700 e/
Stocks, Dec. 31: Producers	12,600	9,220	5,980	5,710	6,390
World: Production	139,000	119,000	128,000	130,000 r/	133,000 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits.

2/ Average value based on the sold or used values.

3/ Includes domestic sales and exports.

4/ Total value of all domestic and export sales.

5/ Exports reported to the U.S. Geological Survey by companies.

6/ Source: Bureau of the Census.

7/ Some phosphate rock import tonnage and value were suppressed by the Bureau of the Census.

8/ Expressed as sold or used plus imports minus exports. Includes some estimated phosphate rock tonnage imported from Morocco not reported by the Bureau of the Census in 1994, 1995, and 1996.

TABLE 2
PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES, BY REGION 1/

(Thousand metric tons and thousand dollars)

	Mine production (crude ore)		Marketable production			
			Beneficiated			Ending stocks, rock
Period/region	Rock	P2O5 content	Rock	P2O5 content	Value 2/	
1995	165,000	25,300	43,500	12,800	947,000	5,710
1996:						
January-June:						
Florida and North Carolina	84,600	11,900	19,900	5,890	464,000	4,730
Idaho and Utah	4,960	1,130	2,790	733	58,000	2,150
Total	89,500	13,100	22,700	6,630	522,000	6,880
July-December:						
Florida and North Carolina	85,100	9,740	19,300	5,680	464,000	4,700
Idaho and Utah	3,880	997	3,430	997	77,200	1,690
Total	89,000	10,700	22,700	6,680	541,000	6,390
Grand total	179,000	23,800	45,400	13,300	1,060,000	XX

XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Average value based on the sold or used values.

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TABLE 3
PHOSPHATE ROCK SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY GRADE AND REGION 1/

(Thousand metric tons and thousand dollars)

Period and grade (percent BPL 2/ content	U.S. total Rock	U.S. total P2O5 content	U.S. total Value 3/
January-June 1995	22,100	6,530	452,000
July-December 1995	21,600	6,440	498,000
Total	43,700	13,000	950,000
January-June 1996:			
66 to less than 70	13,900	4,200	310,000
60 to less than 66	5,520	1,560	118,000
Other 4/	1,800	559	58,100
Total	21,200	6,320	486,000
July-December 1996:			
66 to less than 70	W	W	W
60 to less than 66	18,600	5,460	439,000
Other 4/	3,780	1,150	92,600
Total	22,400	6,610	532,000
Grand total	43,500	12,900	1,020,000
Florida and North Carolina	38,100	11,300	902,000
Idaho and Utah	5,460	1,620	116,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P2O5.

3/ F.o.b. mine.

4/ Includes below 60 and 70 to greater than 74% BPL content.

TABLE 4
PHOSPHATE ROCK SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY USE AND REGION 1/

(Thousand metric tons)

Period and use	Region: Florida and North Carolina Rock	Region: Florida and North Carolina P2O5 content	Region: Idaho and Utah Rock	Region: Idaho and Utah P2O5 content	United States: Total Rock	United States: Total P2O5 content
1995	38,100	11,400	5,620	1,600	43,700	13,000
1996:						
January-June:						
Domestic:						
Agricultural	17,600	5,270	1,530	442	19,100	5,720
Industrial	36	12	1,010	287	1,050	299
Subtotal	17,600	5,290	2,530	729	20,200	6,020
Exports: 2/	955	302	--	--	955	302
Total	18,600	5,590	2,530	729	21,200	6,320
July-December:						
Domestic:						
Agricultural	18,900	5,560	1,560	523	20,500	6,080
Industrial	W	W	1,370	368	W	W
Subtotal	W	W	2,930	891	W	W
Exports: 2/	W	W	--	--	W	W
Total	19,400	5,720	2,930	891	22,400	6,610
Grand total	38,100	11,300	5,460	1,620	43,500	12,900

W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Exports reported to the U.S. Geological Survey by companies.

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TABLE 5
VALUE OF U.S. PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, f.o.b. mine)

Grade	1995			1996		
(percent BPL 1/ content)	Domestic	Export	Average	Domestic	Export	Average
74 or more	--	--	--	W	--	W
72 to less than 74	30.40	32.97	31.30	W	W	W
70 to less than 72	22.88	29.74	26.64	W	W	W
66 to less than 70	20.90	25.55	21.15	22.29	30.14	22.62
60 to less than 66	22.15	--	22.15	23.00	W	23.14
Less than 60	17.02	--	17.02	W	--	W
Weighted average	21.29	28.35	21.75	22.90	35.82	23.40

W Withheld to avoid disclosing company proprietary data.
1/ 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P2O5.

TABLE 6
U.S. EXPORTS OF GROUND AND
UNGROUND PHOSPHATE ROCK 1/

(Thousand metric tons)

	Quantity	
Country	1995	1996
Australia	211	132
Belgium	268	--
Canada	137	12
India	359	223
Japan	463	269
Korea, Republic of	993	724
Netherlands	270	57
New Zealand	128	71
Other	161	81
Total	2,990	1,570

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 7
U.S. EXPORTS OF SUPERPHOSPHATES
(CONCENTRATED)

(Thousand metric tons)

	Quantity	
Country	1995	1996
Argentina	19	1
Australia	202	267
Bangladesh	21	--
Brazil	34	76
Canada	18	19
Chile	108	141
Japan	58	38
Peru	--	18
Uruguay	15	13
Other	239	109
Total	714	681

Source: Bureau of the Census.

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TABLE 8
U.S. EXPORTS
OF DIAMMONIUM PHOSPHATE

(Thousand metric tons)

Country	Quantity	
	1995	1996 2/
Argentina	232	402
Australia	438	599
Belgium	103	--
Brazil	59	29
Canada	80	119
Chile	41	51
China	5,600	3,880
Colombia	130	68
Dominican Republic	47	37
Ecuador	69	32
France	35	--
Germany	53	32
Guatemala	9	24
India	1,110	245
Iran	270	--
Japan	501	421
Kenya	11	54
Mexico	40	149
New Zealand	182	181
Pakistan	194	569
Thailand	160	244
Turkey	157	17
Uruguay	69	107
Other	474	660
Total	10,100	7,920

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data under review by Bureau of the Census.

Source: Bureau of the Census.

TABLE 9
U.S. EXPORTS OF
MONOAMMONIUM PHOSPHATE 1/

(Thousand metric tons)

Country	Quantity	
	1995	1996
Australia	182	318
Brazil	77	166
Canada	505	542
Chile	44	59
Colombia	74	69
Guatemala	27	24
Japan	131	104
Mexico	52	101
New Zealand	14	--
Thailand	8	44
Other	90	84
Total	1,200	1,510

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 10
U.S. EXPORTS OF
PHOSPHORIC ACID 1/

(Thousand metric tons)

Country	Quantity	
	1995	1996
Australia	1	122
Canada	137	73
India	157	130
Indonesia	36	--
Venezuela	61	60
Other	183	185
Total	575	570

1/ Excludes superphosphoric acid tonnage.

Source: Bureau of the Census as adjusted by the U.S. Geological Survey.

TABLE 11
U.S. EXPORTS OF ELEMENTAL PHOSPHORUS 1/

Country	1995		1996	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Brazil	98	$202	3	$5
Canada	682	1,230	1,250	2,370
Japan	7,310	13,600	4,760	9,570
Korea, Republic of	194	432	30	57
Mexico	5,280	8,130	6,250	12,500
Netherlands	40	99	40	108
Other	149	345	281	948
Total	13,700	24,100	12,600	25,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ F.a.s. values.

Source: Bureau of the Census.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF PHOSPHATE ROCK AND
PHOSPHATIC MATERIALS 1/

(Thousand metric tons and thousand dollars)

Phosphatic materials	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Natural calcium phosphates, unground	618	32,800	575	33,100
Natural calcium phosphates, ground	56	3,140	(3/)	117
Dicalcium phosphate	3	4,660	4	5,530
Phosphorus	2 r/	3,920 r/	1	3,280
Normal superphosphate	(3/)	57	(3/)	33
Triple superphosphate	25	4,720	83	7,650
Diammonium phosphate	21	6,010	77	18,300
Fertilizer containing nitrates and phosphates	51	6,490	69	12,300
Phosphoric acid	1	548	32	7,010

r/ Revised.
1/ Data are rounded to three significant digits.
2/ Declared c.i.f values.
3/ Less than 1/2 unit.

Source: Bureau of the Census as adjusted by the U.S. Geological Survey.

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TABLE 13
PHOSPHATE ROCK ANNUAL
WORLD PRODUCTION CAPACITY,
DECEMBER 31, 1996

(Thousand metric tons per year)

Region/country	Capacity	Percent
United States	51,000	31
Africa	45,700	28
Asia	28,800	17
Western Europe and the Former U.S.S.R.	20,900	13
Middle East	12,400	8
Latin America	5,300	3
Oceania	1,300	1
World total 1/	165,000	100

1/ Data may not add to totals shown because of independent rounding.

Sources: International Fertilizer Industry Association and the U.S. Geological Survey.

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TABLE 14
PHOSPHATE ROCK, BASIC SLAG, AND GUANO: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Commodity and country 3/	Gross weight					P_2O_5 content				
	1992	1993	1994	1995	1996 e/	1992	1993	1994	1995	1996 e/
Phosphate rock:										
Albania e/	2	2	2	2	2	(4/)	(4/)	(4/)	(4/)	(4/)
Algeria	1,136	718	738	757	760	340 e/	220 e/	226	232	230
Australia	2	2	2 e/	2 e/	2	(4/)	(4/)	(4/) e/	(4/) e/	(4/)
Brazil	2,825 r/	3,419 r/	3,937 r/	3,590 r/	3,600	650	700	700	700 e/	700
Chile	18	15	10	10 e/	10	5	4	3	3 e/	3
China e/	21,400	21,200	24,100 r/	19,300 r/	21,000	6,400	6,350	7,430 r/	5,790 r/	6,300
Colombia e/	32 5/	45 5/	48 5/	50	50	7	9	10	11	11
Egypt e/	2,000 5/	1,585 5/	1,500	1,500	1,500	500	390	390	390	390
Finland	555	628	647	671	600	201	227	236	244	216
India e/	488 5/	969 5/	1,176 5/	1,250	1,300	132	262	318	338	351
Indonesia e/	8	7	7	8	8	2	2	2	2	2
Iraq e/ 6/	600	800	1,000	1,000	1,000	180	240	300	300	300
Israel 6/	3,595	3,680	3,961	4,063	3,800	1,130 e/	1,148	1,232	1,264	1,140
Jordan	4,296	4,129	4,217	4,984	5,350	1,410 e/	1,367	1,399	1,655	1,820
Kazakstan e/	7,000	4,000	2,000	2,200	500	1,750	1,000	500	550	125
Korea, North e/	500	510	510	520	520	160	163	163	164	164
Mexico 7/	515	237	533	622 r/	625	160 e/	72	156	180	183
Morocco 8/	19,145	18,193	19,764	20,200	20,800	6,180 e/	5,778	6,274	6,381	6,550
Nauru	747	634	613	496	510 5/	288	244	233	190	194 5/
Netherlands Antilles e/	15	10	15	-- r/	--	5	3	5	-- r/	--
Pakistan e/	20 5/	14 5/	15 5/	10 r/ 5/	10	6	4	3 r/	2 r/	2
Peru	37	37	37	37 e/	37	12	12	12	12 e/	12
Philippines e/	5 5/	92 5/	20	20	20	2	31	7	7	7
Russia e/	11,500	9,400	8,000	8,800	8,500	4,000	3,300	2,800	3,000	2,900
Senegal e/ 9/	2,284 5/	1,667 5/	1,587 r/ 5/	1,500 r/	1,600	830	606	576 r/	545 r/	600
South Africa	3,080	2,466	2,545	2,790	2,700	1,170 e/	962	995	1,087	1,000
Sri Lanka e/	26 5/	36 5/	32 5/	32	32	6	12	11	11	11
Syria	1,266	931	1,203	1,551	2,000	395 e/	286	371	477	615
Tanzania e/	5 r/ 5/	4 r/ 5/	-- r/	-- r/	--	2 r/ e/	1 r/ e/	-- r/	-- r/	--
Thailand	8	11	8 r/	9 r/	9	2	3	2 r/	3	3
Togo e/	2,083 5/	1,794 r/ 5/	2,149 r/ 5/	2,560 r/	2,600	760	540 5/	800	720	720
Tunisia	6,400	5,500	5,699	7,241	7,100	1,890 e/	1,647	1,712	2,182	2,080
Turkey	65	78	-- r/	-- r/	--	20	24	-- r/	-- r/	--
United States	47,000	35,500	41,100	43,500	45,400	14,100	10,700	12,100	12,800	13,300
Venezuela	10	--	99 r/	86 r/	203 p/	3	--	27 r/	23 r/	55 p/
Vietnam e/	290 5/	363 5/	470 5/	480	480	93	116	144	145	145
Zimbabwe, concentrate	142	153	151	154 r/	123 5/	42	45	45	45 e/	39
Total	139,000	119,000	128,000	130,000 r/	133,000	42,800	36,500	39,200 r/	39,400 r/	40,200

See footnotes at end of table.

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TABLE 14--Continued

PHOSPHATE ROCK, BASIC SLAG, AND GUANO: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Commodity and country 3/	Gross weight					P_2O_5 content				
	1992	1993	1994	1995	1996 e/	1992	1993	1994	1995	1996 e/
Basic (Thomas converter) slag:										
Egypt e/	8	8	8	8	8	2	2	2	2	2
France	356	253	155	140 r/ e/	150	64	46	28	18 r/ e/	27
Germany	120	110	134	125 e/	125	18	16	20	19 e/	19
Luxembourg e/	519 5/	555 5/	472 5/	500	500	93	100	85	75	75
Total	1,000	926	769	773 r/ e/	783	177	164	135	114 r/ e/	123
Guano:										
Chile	(4/)	--	--	--	--	(4/) e/	--	--	--	--
Philippines e/	(4/) 5/	5 5/	5	5	5	(4/)	2	2	2	2
Total e/	1 5/	5 5/	5	5	5	(4/)	2	2	2	2

e/ Estimated. p/ Preliminary. r/ Revised.

1/ Table includes data available through May 8, 1997. Data for major phosphate rock-producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

2/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Belgium may have produced small quantities of phosphate rock and Namibia may have produced small quantities of guano, but output is not officially reported; available information is inadequate for formulation of reliable estimates of output levels.

4/ Less than 1/2 unit.

5/ Reported figure.

6/ Beneficiated.

7/ Includes only output used to manufacture fertilizers.

8/ Production from Western Sahara area is included.

9/ Does not include aluminum phosphate production, gross weight estimated at 75,000 metric tons per year.

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PLATINUM-GROUP METALS

By Henry E. Hilliard

Six metals, (platinum, palladium, rhodium, iridium, ruthenium, and osmium) make up the platinum group metals (PGM). Of the six metals, platinum and palladium are the most important commercially. PGM are used as catalysts in the automotive, chemical, and petroleum refining industries. PGM are also used in the electrical and electronic, dental and medical, and jewelry industries.

Although the metals of the group generally are found together, minable deposits of the PGM are very rare. Often, the PGM are byproducts of the mining of some other metal, usually nickel or copper. The major PGM mining countries are, in order of importance, South Africa, Russia, Canada, and the United States.

Identified world PGM resources at yearend 1996 were estimated at 100 million kilograms. The reserve base was estimated at 66 million kilograms and reserves at 56 million kilograms. Of the reserve base and the reserves, South Africa had nearly 90% of each; Russia had 9% and 11%, respectively; and the United States had 1% and 0.4%, respectively.

In the United States, the Stillwater Mine, in Montana, accounts for nearly all domestic primary PGM production. Production at the Stillwater Mine, consisting primarily of palladium and platinum, increased in 1996, reflecting the progress made in the company's 4-year plan to increase ore production from 336,000 metric tons per year to more than 660,000 tons per year by mid-1997. In 1995, the Stillwater Mine produced 1,590 kilograms of platinum and 5,260 kilograms of palladium; while in 1996, the mine produced nearly 1,840 kilograms and 6,100 kilograms of platinum and palladium, respectively (Stillwater Mining Company, 1997). Among the accomplishments in 1996 were the commissioning of the 530-meter shaft adjacent to the concentrator for hoisting miners, materials, and development waste, and construction and commissioning of a base metal refinery adjacent to the smelter. The new refinery, with a capacity of nearly 4,000 tons, uses the Sherritt Process to enrich the smelter product by dissolving contained nickel and copper using sulfuric acid. Although the Stillwater Mining Co. concentrates and smelts the ore from the Stillwater Mine locally, the company shipped the resulting PGM-bearing matte to one domestic and one foreign refinery for further processing.

The remaining domestic primary PGM production were byproducts of the refining of primary copper; they were recovered from anode slimes at two copper refineries in Texas and Utah. In addition to the small amount of byproduct production, about 20 refiners, located primarily on the east and west coasts, recovered PGM from scrap material. Other companies located throughout the United States collected scrap materials, such as catalysts and PGM-bearing solutions, and processed them to increase the grade. These upgraded secondary materials were then sold to refiners. Most companies specialized in refining or upgrading a particular type of scrap. Because of their high value, PGM are routinely recovered from petroleum catalysts, chemical catalysts, automobile catalysts, glass fiber bushings, electronic scrap, laboratory equipment, dental materials, and jewelry. PGM were sold by at least 90 processors and dealers, largely in the Northeast.

The principal domestic use of PGM was in the catalytic converters of automobiles and light trucks, where they reduce the carbon monoxide, unburned hydrocarbons, and nitrogen oxides in exhaust gases to tolerable levels. Other automotive applications include oxygen sensors and certain types of spark plugs, both of which used small quantities of platinum.

The nonautomotive applications of PGM were numerous. The petroleum refining industry used PGM, principally platinum, in reforming, cracking, and isomerization reactions. Other PGM catalyst applications include the syntheses of nitric acid and hydrogen cyanide using platinum and rhodium, and the production of hydrogen peroxide using palladium. PGM catalysts were also used to produce a variety of organic chemicals.

Electronic applications for PGM include the production of thick-film resistors using ruthenium, the production of thick-film conductors using palladium, and the use of platinum "targets" for sputtering thin films on circuit boards. Platinum-rhodium alloys were used in thermocouples for precise temperature measurement.

In addition, platinum, rhodium, and palladium were used in the "bushings" through which textile (continuous filament) glass fiber is extruded.

The Engelhard average price for unfabricated platinum decreased from $425.32 per troy ounce for 1995 to $398.17 per ounce for 1996. Similarly, the Engelhard average price for palladium decreased from $153.46 for 1995 to $130.41 for 1996. For 1996, the Engelhard average price for iridium was $74.00; for rhodium, $308.80; and for ruthenium, $47.56. In 1995, the average prices were $74.14, $464.66, and $26.72 per ounce for iridium, rhodium, and ruthenium, respectively.

Platinum stocks held by the New York Mercantile Exchange (NYMEX) increased to 2,844 kilograms at yearend 1996 from 1,188 kilograms at yearend 1995. NYMEX yearend palladium stocks rose to 3,064 kilograms from 2,149 kilograms. Stocks of PGM held by the Federal Government in the National Defense Stockpile remained unchanged from the previous year, and at yearend 1996 consisted of 14,100 kilograms of platinum, 39,300 kilograms of palladium, and 920 kilograms of iridium.

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The United States remained dependent on imports of PGM. For the period 1992-96, the United States imported more than 318,000 kilograms of platinum. Of this amount, South Africa supplied approximately 60%, the United Kingdom 10%, and Russia 9%. During the same period, the United States imported more than 500,000 kilograms of palladium. The major source countries were Russia, 42%; South Africa, 22% and the United Kingdom, 11%. All unwrought and semimanufactured PGM can be imported duty free.

Although platinum, palladium, and rhodium are so efficient in automotive catalysts that they have no competitive substitutes, the percentage of each metal used in the catalyst can be varied. Silver and gold are alternatives for platinum and palladium in many end uses, including electrical and electronic applications, jewelry, and dental applications.

World Review

Johnson Matthey estimated that world demand for platinum, nearly 152 tons, was essentially unchanged in 1996 (Johnson Matthey, 1997). Although platinum use in automotive catalysts declined owing in part to a shift by some manufacturers to palladium-rich catalysts, the decline was more than offset by the estimated increase in demand for platinum in the form of small investment items, for jewelry, and for petroleum catalysts. Similarly, the world demand for palladium in 1996, as estimated by Johnson Matthey, also remained essentially unchanged from that of 1995. Increased demand for palladium for automotive catalysts was more than offset by lower demand for electrical applications.

South Africa.—South Africa remained the world's largest PGM producer, accounting for 80% of platinum production and 44% of palladium production. Essentially all of South Africa's PGM output was produced by 10 mines, 9 of which are underground operations, mining the Bushveld Complex. The Bushveld Complex, and the Stillwater Complex in the United States, are the only deposits in the world mined primarily for their PGM content.

Other.—Canada and Russia are the other major producers of PGM. For both countries, PGM are byproducts of their nickel operations, primarily in the Sudbury District of Canada, and the Noril'sk-Talnakh region of Russia.

Outlook

Given the strong demand for a cleaner environment, worldwide demand for PGM is expected to grow moderately over the next few years. Many countries already require the use of catalytic converters for controlling emissions from gasoline-powered automobiles, and other countries are expected to adopt these requirements. Although both platinum and palladium are used in catalytic converters, in the short-term, platinum is expected to remain the dominant metal, owing primarily to the need to use up to three times as much palladium to obtain the desired emissions reduction. Domestically, moderate growth for PGM demand is also expected over the next few years as increasingly stringent standards for automobile emissions are adopted.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF PLATINUM GROUP METALS IN 1996 1/

(Kilograms)

Country	Ores and concentrates	Waste and scrap	Refined					
			Platinum	Palladium	Rhodium	Iridium	Osmium	Ruthenium
Imports:								
Australia	--	107	389	--	304	--	--	--
Belgium	--	146	2,300	8,760	--	--	--	--
Canada	--	251	2,170	3,610	(2/)	(2/)	--	(2/)
Chile	--	5	80	--	--	--	--	--
China	--	--	70	1,230	--	--	--	--
Colombia	--	50	544	--	--	--	--	--
France	--	324	43	121	122	1	--	5
Germany	--	195	4,190	2,810	232	53	--	414
Hong Kong	--	172	--	--	--	--	--	--
India	--	--	--	70	19	--	--	--
Ireland	--	--	--	205	--	--	--	--
Italy	--	5	187	247	8	1	--	(2/)
Japan	--	151	259	4,400	43	--	--	--
Mexico	101	222	16	3	2	--	--	--
Netherlands	--	808	54	(2/)	--	1	--	4
Norway	--	--	281	2,270	21	--	--	--
Russia	1,860	172	10,600	83,100	1,970	--	--	922
South Africa	--	126	42,900	24,100	6,020	1,130	(3/)	13,200
Switzerland	--	--	3,100	4,920	80	58	--	701
United Kingdom	--	1,910	8,320	9,890	835	565	--	828
Other	--	411	296	174	--	--	--	--
Total	1,960	5,060	75,800 4/	146,000	9,650	1,810	(3/)	15,600
Exports:								
Australia	--	--	48	49	--	4 5/		
Belgium	--	1,050	2,770	5,550	--	(2/)		
Canada	8	168	418	927	(2/)	3 5/		
Chile	--	--	48	1	--	--		
Finland	--	--	545	--	--	--		
France	--	20	351	392	1	--		
Germany	40	1,050	1,420	1,580	18	18 5/		
Hong Kong	4	(2/)	319	179	6	4		
Ireland	--	--	310	213	76	(2/)		
Israel	--	--	--	177	(2/)	--		
Italy	--	22	135	506	(2/)	4 5/		
Japan	7	924	1,960	2,300	6	20 5/		
Korea, Republic of	3	(2/)	1,930	983	70	13 5/		
Malaysia	--	--	452	7	--	--		
Mexico	5	1	42	4,380	--	4 5/		
Netherlands	--	129	127	4,130	(2/)	10 5/		
Singapore	--	--	31	463	--	--		
South Africa	4	--	--	163	--	--		
Sweden	--	145	69	148	--	1 5/		
Switzerland	238	--	127	522	(2/)	(2/)		
Taiwan	--	--	48	1,780	(2/)	2		
United Kingdom	152	5,110	1,360	2,080	10	26 5/		
Uruguay	--	--	55	--	--	--		
Venezuela	--	1	107	--	(2/)	--		
Other	26	18	78	193	--	15 5/		
Total	487	8,640	12,700	26,700	187	122 5/		

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Data withheld pending verification by the Bureau of the Census.
4/ Of this amount, 2,070 kilograms was in the form of platinum coins.
5/ Includes osmium and ruthenium.

Source: Bureau of the Census.

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TABLE 2
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country 3/	1992	1993	1994	1995	1996 e/
Platinum:					
Australia e/ 4/	100	100	100	100	100
Canada e/ 5/	4,800	5,000	6,000	9,320 r/	8,260
Colombia	1,956	1,722 r/	1,084 r/	973 r/	669 6/
Ethiopia e/	1	--	--	--	--
Finland e/	60	60	60	60	60
Japan 7/	629	661	691	730 r/	850
Russia e/	28,000	20,000	15,000	18,000	18,000
Serbia and Montenegro	19	10	10 e/	10 e/	10
South Africa e/ 5/	94,900	109,000	114,000	118,000	117,000
United States e/ 8/	1,650 r/	2,050 r/	1,960 r/	1,590 r/	1,840
Zimbabwe	9	4	7	10 e/	10
Total	132,000	139,000	139,000	149,000 r/	146,000
Palladium:					
Australia e/ 4/	400	400	400	400	400
Canada e/ 5/	5,800	6,000	7,000	5,950 r/	5,270
Finland e/	100	100	100	100	100
Japan 7/	986	1,183	1,277	2,174 r/	2,300
Russia e/	70,000	50,000	40,000	48,000	48,000
Serbia and Montenegro	130	72	50	50 e/	50
South Africa e/ 5/	41,000	48,000	47,800	49,400	48,900
United States e/ 8/	5,440 r/	6,780 r/	6,440 r/	5,260 r/	6,100
Zimbabwe	19	11	17	20 e/	20
Total	124,000	113,000	103,000	111,000 r/	111,000
Other platinum-group metals:					
Canada e/ 5/	1,310	1,440	1,970	803 r/	712
Russia e/	6,000	4,000	3,000	3,600	3,600
South Africa e/ 5/	17,000	19,000	22,100	22,800	22,500
Total	24,300	24,400	27,100	27,200 r/	26,800
Grand total	280,000	276,000	269,000	287,000 r/	284,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 29, 1997. Platinum-group metal production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

3/ In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan.

4/ Platinum-group metals recovered from nickel ore processed domestically. Platinum-group metals extracted from exported ores are believed to be included in the production figures for Japan and may be included in figures for other receiving countries.

5/ Country reports only total of platinum-group metals produced. Figures for constituent metals are estimates.

6/ Reported figure.

7/ Production derived entirely from imported ores.

8/ Estimates for the Stillwater Mine from published sources. A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.

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POTASH

By James P. Searls

Potash denotes a variety of mined and manufactured salts, all containing the element potassium in water soluble form. Potash can be potassium chloride [KCl, or muriate of potash (MOP)], potassium sulfate [K_2SO_4, or sulfate of potash (SOP)], potassium-magnesium sulfate ($K_2SO_4 \cdot MgSO_4$, or sulfate of potash magnesia), potassium nitrate (KNO_3, or saltpeter), or mixed sodium-potassium nitrate ($NaNO_3+KNO_3$, or Chilean saltpeter).

The term "potash" was originally applied to potassium carbonate/potassium hydroxide crystals that were recovered in iron "pots" from leaching wood (or other plant) "ashes" with water. That material was considered to be an industrial product, because it was too expensive to use as a fertilizer. As a fertilizer, potassium in water-soluble form activates plant enzymes, maintains cell-wall shape through interior fluid pressure, aids photosynthesis in the leaves, helps transport sugars and starches up and down the plant stem, aids in nitrogen uptake and protein synthesis, strengthens plant stems, increases disease resistance, and increases plant resistance to stress.

Potash is used primarily as an agricultural fertilizer (plant nutrient) because it is a source of soluble potassium, one of the three primary plant nutrients; the others are fixed nitrogen and soluble phosphorus. Potash and phosphorus are mined products, and fixed nitrogen is produced from the atmosphere by using industrial processes. There are no substitutes for these three plant nutrients, but there are minor sources of plant nutrients, such as animal manure, bone meal, guano, "tankage" from slaughterhouses, and glauconite. Modern agricultural practice uses these primary nutrients in large amounts plus additional nutrients, such as boron, calcium, chlorine, copper, iron, magnesium, manganese, molybdenum, sulfur, and zinc, to assure plant health and proper maturation.

Legislation and Government Programs

In 1987, there was an antidumping investigation of the Canadian potash producers resulting in a suspension of the antidumping duty investigation agreement in early 1988 (U.S. Department of Commerce, International Trade Agency, Import Administration, 1988). In January 1993, this agreement was extended by the U.S. Department of Commerce for an indefinite period (IMC Global Inc., 1996, p. 21), with one domestic company responsible for continuing the suspension. That one domestic company now includes the three original petitioners. The intent of the agreement is to prevent the sale of Canadian potash into the United States at no less than "fair value."

In 1993, the Antitrust Division of the U.S. Department of Justice initiated a grand jury investigation into allegations that the North American potash producers acted together to fix the price of potash sold in the United States between 1987 and 1994. In June 1996, the companies remaining under investigation were advised that the investigation had been concluded, and a spokesperson for the Antitrust Division stated that no action would be taken (IMC Global Inc., 1996, p. 9).

The consolidated class action suit against most of the North America potash producers filed by the direct purchasers in Federal District Court in St. Paul, MN, alleging actions to fix the price of potash sold in the United States received a setback in September. The Federal Magistrate overseeing the case formally recommended to the presiding judge dismissal of the suit by summary judgment. Indirect purchasers residing in California have filed in California State courts for the same allegations. At the end of the year, the California suits were still preliminary with no discovery proceedings having occurred (IMC Global Inc., 1996, p. 9.

Production

Production of all types and grades of potash in the United States in 1996 declined from 1.5 million metric tons, K_2O equivalent[1], to 1.4 million tons. Sales of all types and grades of U.S. produced potash were unchanged from 1995's level of about 1.4 million tons and the marketable potash value, f.o.b. mine, of about $299 million increased less than 8% from 1995.

The U.S. Geological Survey developed potash domestic data from voluntary semiannual surveys of U.S. operations. Of the 10 survey requests per half year sent to operations, nine responded. Data from the responses are estimated to consist of about 98% of total production shown in Table 1.

In the beginning of 1996, the Carlsbad, NM, potash producers were Eddy Potash Inc. (EP), owned by Trans-Resources, Inc.; IMC Global Operations Inc., owned by IMC Global Inc.; Mississippi Potash, Inc. (MP), owned by Mississippi Chemical Corp.; New Mexico Potash, Inc. (NMP), owned by Trans-Resources; and Western Ag-Minerals Inc., owned by Rayrock Resources of Toronto, Canada. In the first quarter of 1996, IMC Global Inc. and The Vigoro Corp. merged into a single company. The potash portion of the company was named IMC Kalium and includes two domestic operations, one in Carlsbad and the other in Hersey, Michigan. The Carlsbad operation produces muriate of potash, sulfate of potash, and slfate of potash-magnesia. In the third quarter of 1996,

[1]All tonnages are reported in metric tons, K_2O equivalent, unless otherwise noted.

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Mississippi Chemical completed negotiations with Trans-Resources to purchase EP and NMP. The purchase was valued at $45 million plus an adjustment for current working capital of about $11 million. EP became a wholly owned subsidiary of MP, and NMP was merged into MP (Mississippi Chemical Corp., 1997). MP annual capacity was reported to be about 232,000 tons, and the combined annual capacity of EP and NMP was placed at 481,000 tons. These three operations produce only muriate of potash. Western Ag-Mineral reported that it had brought a continuous miner into its langbeinite mine (Green Markets, 1996c) and the miner was working well. This mine has traditionally been an undercut-drill-blast-load operation because the ore was thought to be too hard for mechanical miners. At the end of the year, only three companies, IMC Kalium, MP, and Western Ag-Mineral, were operating in Carlsbad, NM. Potash Corporation of Saskatchewan Inc. (PCS) of Canada continued to market potash exports for three New Mexico operations, now in a single company owned by Mississippi Chemical, as a cost-cutting effort for the producers.

In Utah, producers were Great Salt Lake Minerals Corp. (GSLMC), affiliated with Harris Chemical North America Inc.; Moab Salt Inc., owned by PCS; and Reilly-Wendover of Reilly Industries Inc. GSLMC has increased its production above the 1984 capacity of 100,000 tons per year but has not reached the target capacity of 200,000 tons per year (Fertilizer Markets, 1996c: Green Markets, 1996a). The company announced a further capacity target of 280,000 tons per year by September 1997. Reilly-Wendover signed an agreement with the U.S. Bureau of Land Management and the State of Utah School and Institutional Trust Lands Administration to add salt to parts of the surface of the Bonneville Salt Flats over a 5-year period beginning on September 1, 1995 (Barrett, 1995). Reilly will annually flood the international raceway area with saturated salt (NaCl) water, the salt coming from an evaporation pond. The natural evaporation of salt-saturated water will cause crystals of salt to form, thickening the surface of the Salt Flats by 1.1 centimeters per year. The flooding will supply more than 900,000 tons per year of salt. Reilly Industries has set aside a fund of $800,000 to fund the salt-surface replenishment. There had been concern by the operators of the international raceway area that the salt layer had become dangerously thin for speeding vehicles.

In California, North American Chemical Co., managed by Harris Chemical North America Inc., produced soda ash, salt cake, borax pentahydrate, muriate of potash, and sulfate of potash. Beginning in April 1996, the muriate of potash and sulfate of potash circuits were permanently shut down (Fertilizer Markets, 1996d ; Green Markets, 1996b). From April on, North American Chemical sold SOP from GSLMC and was a dealer for a Canadian MOP producer to its historical domestic customers.

In Michigan, IMC Kalium produced MOP from a deep solution mine at the Hersey mine. Capacity was scheduled to rise from 30,000 tons per year to 90,000 tons per year, and to be completed by April 1997.

MOP accounted for 61% by tonnage of total domestic sales but only 39% of sales by dollars, and SOP accounted for about 21% of tonnage and 31% of sales by dollars. The "Other" category accounted for 18% of tonnage and 30% of sales by dollars.

Consumption

The poor harvest of 1995 with the resulting reduction of potash removal from the soil by harvesting the crop left a higher-than-normal residual potash in the soil for the beginning of 1996. This type of situation usually causes a reduced level of potash consumption in the ensuing year. Also, the floods and the droughts in spring 1996 prevented some fertilizer application. Futures market prices for grains, however, climbed through March and April, reaching 20-year highs in May and June. Extraordinary price expectations usually stimulate increased planting and fertilizer application. These strong, opposing stimuli canceled each other and potash consumption was only slightly above the 1995 level.

Apparent consumption of potash in the United States increased about 1% or 70,000 tons from that of 1995. Domestic sales in the domestic market decreased by about 4%, or 42,000 tons, and imports from Canada increased about 1% or 48,000 tons. Imports from other countries increased by about 25%, or 120,000 tons. Imports for Belarus fell from 94,000 tons to zero, and imports from Russia increased from 100,000 tons to 260,000 tons.

According to the Potash & Phosphate Institute, shipments of agricultural potash from Canadian and U.S. producers decreased by about 6%, and those of nonagricultural potash increased by 10% for a total decrease of 4% from 1995. The States receiving the largest shipments of agricultural potash from Canadian and U.S. producers were, in decreasing order, Illinois, Iowa, Ohio, Minnesota, Indiana, Wisconsin, and Missouri. These seven States received about 50% of the total North American producers' agricultural shipments to U.S. consumers. Coarse muriate of potash was 55% of the 3-muriates of potash received from Canada. Coarse muriate of potash was 3% of the domestic producer's 3-muriates of potash sales in 1996. Domestic producers accounted for about 1% of the shipments to Illinois, 11% to Iowa, 5% to Ohio, about 1% to Minnesota, 2% to Indiana, about 1% to Wisconsin, and about 50% to Missouri. The States receiving the largest portion (62%) of domestically produced agricultural potash were, in decreasing order, Texas, Missouri, California, Mississippi, Kansas, and Florida.

The States receiving the most (70% of the total) shipments of nonagricultural potash from Canadian and U.S. producers were, in decreasing order, Alabama, Wisconsin, Ohio, and Delaware.

Stocks

Yearend stocks decreased about 15% compared with those of 1995. Yearend stocks represented about 19% of annual production, or about 10 weeks of average production.

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Prices

The weighted average price per ton K_2O equivalent f.o.b. mine for all types and grades of U.S. potash sales was $208.80 for the full year, an increase of about 3% compared with that of 1995, and $203.70 for the first half of the year, and $215 for the second half of the year. The weighted average annual prices for standard grade muriate of potash per ton f.o.b. mine was $133.53, down 3% from 1995; coarse grade, $128.34, up 2% from 1995; and granular grade, $133.15, down 4% from 1995. The weighted average annual price for the three muriates of potash per ton f.o.b. mine was $133.10, a decrease of 3% from 1995.

Foreign Trade

Total potash exports of the United States increased by about 18%, by tonnage, as reported by the Bureau of Census. Muriate of potash was about 50% of exports, sulfate of potash was about 30%, sulfate of potash-magnesia was 19%, and nitrate of potash was 1%. Muriate of potash exports increased by 33%, and sulfate of potash exports decreased slightly compared with those of 1995. The major destinations for U.S. potash exports were countries in Latin America and the Pacific Basin. Latin America received about 62% of total potash exports, including 87% of muriate of potash, 36% of sulfate of potash, and 43% of sulfate of potash-magnesia. Muriate of potash to Latin America increased by about 64% to 206,000 tons. The Pacific Basin received about 24% of total potash exports, including 53% of sulfate of potash and 37% of sulfate of potash-magnesia.

Potash imports for consumption into the United States increased slightly, as reported by the U.S. Bureau of the Census. Ninety-three percent of potash imports came from Canada.

World Review

The estimate of world production for 1996 is 23.9 million tons, about 800,000 tons below that of 1995 and based on lower sales to India and China. Those two countries may have bought more potash than they needed in 1995 and used the spare tonnage in 1996 as leverage to either force down the price or arrest price increases.

Argentina.—In Argentina, the CRA Ltd., now Dual Listed Company with The RTZ Corporation PLC, withdrew from the Potasio Rio Colorado project after a feasibility study judged the project insufficiently promising (Fertilizer International, 1996b, Fertilizer Markets, 1996j).

Brazil.—The Government of Brazil began the privatization of the Companhia Vale do Rio Doce, the present lessee of the potash mine at the Tarquari-Vassouras Mine. There has been public opposition to the privatization so the outcome of this effort was unforeseeable.

Belarus.—In 1996, Belarus potash operations operated at about 50% capacity to maintain product stocks below levels that would trigger downward pressure on prices. This was difficult for the miners, because the mining operations often support the schools, hospitals, and other town facilities in their areas.

Canada.—PCS operated at 46% capacity in 1996, [in the Province of Saskatchewan, not including the Patience Lake Mine] (Potash Corporation of Saskatchewan, 1997), by temporarily shutting down mines and mills to control the size of their stocks of finished products. Other Canadian producers operated at larger fractions of their capacity.

PCS reached an agreement with the German corporation BASF AG to purchase 51% of Kali und Salz Beteiligungs AG (K&S AG) of Hanover, Germany for deutsche marks (DM) 250 million (Potash Corporation of Saskatchewan Inc., 1996). K&S AG owns 51% of the operating company Kali und Salz GmbH of Kassel, Germany, while the German Government entity Beteiligungs-Management Gesellschaft BerlinmbH, which contributed DM 1.5 billion in 1993, owns 49%. The contribution was through Treuhandanstalt to finance the merger of former East and West German potash producers including the costs of downsizing, modernization, and retirement for redundant workers. K&S AG also owns 50% of Potacan, Ltd. in Toronto, Canada, the operator of the Clover Hill Potash Mine near Sussex, New Brunswick. Potacan was owned in equal parts by Entreprise Minière et Chemique (EMC) of Paris, France, and K&S AG.

PCS, purchased the Texasgulf fertilizer lines (phosphate and potash), White Springs Phosphate (from Occidental Chemical Corp. for phosphate capacity) in 1995, and Arcadian Corp. of Memphis, TN, in 1996, giving PCS a significant portion of the world's nitrogen capacity.

At the end of the year, the four potash producers in Canada were Agrium, IMC Global, Potacan, and PCS. Potacan produces only potash and the others are integrated fertilizer producers. Canpotex Ltd. is the exporting company for all the Saskatchewan potash producers; it does not export New Brunswick mined potash.

Chile.—In Chile, Kap Resources Ltd. projected that the Yolanda Project, which will produce potassium nitrate and iodine, will be ready in summer 1997 (Fertilizer Markets, 1996g). Sociedad Quimica Y Minera de Chile S.A. reported that its Minsal Project began producing potassium chloride at the beginning of 1996 (Fertilizer Markets, 1996e). This potassium chloride was used for converting sodium nitrate to potassium nitrate at the Maria Elena Plant in the caliche ore region of Antafagosta Province and displaced imported Canadian potassium chloride. Boron Chemicals International Ltd. of Canada was reported to be developing a potassium nitrate (with iodine and sodium sulfate) resource known as the Aquas Blancas property, which is about 95 kilometers to the southeast of Antafagosta in a caliche deposit. (Industrial Minerals, 1996a)

Germany.—BASF AG was withdrawing to "core" business by selling its magnetic tape subsidiary and potash subsidiaries. See the Canadian discussion above for the companies and situation of the proposed potash purchase. The German Government Cartel Agency announced its intention to investigate the purchase carefully (Fertilizer Markets, 1996b).

Israel.—In January, Haifa Chemical Ltd. of Trans-Resources

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Inc. of the United States reopened its second potassium nitrate circuit at the Haifa site after repairing the damage of the 1994 fire. Potassium nitrate capacity at Haifa returned to about 140,000 tons (Phosphorus & Potassium, 1996c). In early 1995, Haifa Chemical had started a new, 50,000 tons potassium nitrate circuit at Mishor Rotem.

Italy.—The regional government of Sicily began a search for a private partner to purchase 51% of the potassium sulfate production site in Sicily (Phosphorus & Potassium, 1996e). This site closed during 1992 as a result of water inflows into the mine (Industrial Minerals, 1996b).

Jordan.—Having successfully followed Israel's lead in producing potassium chloride from the Dead Sea, Jordan began a program during the summer to follow Belgium's Tessanderlo Chemie by producing potassium sulfate (and dicalcium phosphate) (Phosphorus & Potassium, 1996d; Fertilizer International, 1996a). Jordan has also began a review of the magnesium and bromine markets for future development.

Russia.—In 1996, Russian potash operations operated at about 50% capacity to maintain product stocks below levels that would trigger downward pressure on prices. This was difficult for the miners, because the mining operations often support the schools, hospitals, and other town facilities in their areas.

Spain.—Since 1992, the Spanish potash industry has modernized to compete in the European Single Market, to make a profit, and to be ready for the cessation of production from the French potash mines in 2004 (Phosphorus & Potassium, 1996a). It improved particle-size production facilities to meet the market's expectations of sizes for blending, upgraded their transportation facilities for rail and truck loading to reach beyond the Spanish borders, and added sales offices in southern France. Also, the European Union's competition agency allowed the former East and West German potash mines to form a single management entity (Kali & Salz AG) only if that entity withdrew from the German-French potash marketing agency in France to allow more competition.

Thailand.—The Government of Thailand restarted investigations of possible ways to mine the carnallite deposit at Bamnet Narong [the Association of South-east Asian Nations (ASEAN) potash mine] and began the development of the salt portion of the mine (Bangkok Post, 1996). Also, Asian Pacific Resources of Canada was hunting for committed partners for the Udon Thani sylvinite resource (Fertilizer Markets, 1996a).

United Kingdom.—Cleveland Potash Ltd. production has been increasing at a steady pace for many years, primarily under the North Sea. Recently the company has begun producing under the North York Moors National Park, which they would like to continue for the remainder of the Boulby Mine's lifetime (Phosphorus & Potassium, 1996b).

Outlook

In the long term, the domestic potash producers will likely maintain their present position in the domestic market and the export market to the Caribbean and west coast of South America. Trade liberalization owing to the Uruaguay Round of GATT should increase potash consumption in the United States through expected increased crop exports, since the U.S. farm industry has traditionally been a relatively efficient and low-cost producer of major crops. Imported potash from Canada will likely supply most of this gain in consumption.

With the amount of overcapacity in evidence in Canada and the former Soviet Union, the prospect for adding new capacity, outside of niche locations in the Pacific Basin, seem futile unless the product is other than muriate of potash and has some natural advantage, in the sense that f.o.b. mine plus transportation cost to a large consuming area is less than the present supplier's total cost to that same area. Until consumption increases around the world, especially Asia and Latin America, and the farmers of Central Europe and the former Soviet Union are able to invest in potash, other fertilizers, and modern farming technology, there will be overcapacity in the worldwide potash industry. Realizing those facts, it becomes a simple exercise in not driving down the price of potash so that present producers leave the industry, only to resurrect old capacity or invest in new capacity 10 years in the future with the ensuing increased demand. Generally, world-wide potash consumption will remain loosely tied to long-term population growth, with adjustments for food type preferences, choices between food and non-food consumer goods, choices between "guns and butter," and present consumption and investment.

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TABLE 1
SALIENT POTASH 1/ STATISTICS 2/

(Thousand metric tons and thousand dollars, unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Production		3,340	3,070	2,830	3,050	2,890
K2O equivalent		1,710	1,510	1,400	1,480	1,390
Sales by producers		3,470	3,030	2,970	2,880	2,960
K2O equivalent		1,770	1,480	1,470	1,400	1,430
Value 3/	dollars	$334,000	$286,000	$284,000	$284,000	$299,000
Average value per ton of product	do.	$96.45	$94.36	$95.93 r/	$96.49 r/	$101.08
Average value per ton of K2O equivalent	do.	$189.36	$192.72	$193.50 r/	$198.13 r/	$208.86
Exports 4/		1,330	935	997	938	1,100
K2O equivalent		663	415	464	409	481
Imports for consumption 4/ 5/		7,010	7,200	7,930	7,960	8,140
K2O equivalent		4,250	4,360	4,800	4,820	4,940
Customs value	do.	$580,000	$578,000	$642,000	$602,000	$563,000
Consumption, apparent 6/		9,150	9,300	9,890	9,900	10,000
K2O equivalent		5,350	5,430	5,810	5,820 r/	5,890
Yearend producers' stocks, K2O equivalent		283	305	234	312	265
World: Production, marketable K2O equivalent		23,900	20,400	23,100	24,700	23,900 e/

e/ Estimated. r/ Revised.

1/ Includes muriate and sulfate of potash, potassium magnesium sulfate, and some parent salts. Excludes other chemical compounds containing potassium.

2/ Data rounded to three significant digits, except prices.

3/ F.o.b. mine.

4/ Excludes potassium chemicals and mixed fertilizers.

5/ Includes nitrate of potash.

6/ Calculated from sales plus imports minus exports.

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TABLE 2
PRODUCTION, SALES, AND INVENTORY OF U.S. PRODUCED POTASH, BY TYPE AND GRADE 1/

(Thousand metric tons and thousand dollars)

Type and grade	Production				Sold or used						Stocks, end of 6-month period			
	Gross weight		K2O equivalent		Gross weight		K2O equivalent		Value e/ 2/		Gross weight		K2O equivalent	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
January-June:														
Muriate of potash, 60% K2O minimum:														
Standard	187	239	114	147	216	255	132	156	18,500	20,600	62	50	26	31
Coarse	45	17	28	10	57	16	35	10	4,200	1,220	9	27	4	17
Granular	490	464	298	283	483	547	294	333	41,900	43,700	122	84	71	52
Chemical	5	7	3	4	5	6	3	4	W	W	3	2	--	1
Potassium sulfate	327	W	167	W	296	W	152	W	49,100	W	116	W	59	W
Other potassium salts 3/	485	W	137	W	512	W	147	W	W	W	171	W	37	W
Total	1,540	1,480	747	715	1,570	1,630	763	784	157,000	159,000	483	530	197 r/	243
July-December:														
Muriate of potash, 60% K2O minimum:														
Standard	273	238	167	146	267	184	163	113	22,200	15,400	68	104	41	63
Coarse	43	(4/)	26	(4/)	26	26	16	16	2,230	2,000	26	2	16	1
Granular	457	443	278	269	412	407	251	248	33,400	33,600	167	120	102	73
Chemical	4	6	3	4	6	5	4	3	W	W	1	3	1	2
Potassium sulfate	250	W	128	W	185	W	94	W	32,300 r/	W	182	W	93	W
Other potassium salts 3/	484	W	132	W	414	W	111	W	W	W	241	W	59	W
Total	1,510	1,410	734 r/	673	1,310	1,330	639	650	127,000	140,000	685	609	312	265
Grand total	3,050	2,890	1,480	1,390	2,880	2,960	1,400	1,430	284,000	299,000	XX	XX	XX	XX

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ F.o.b. mine.

3/ Includes soluble muriate, manure salts, and potassium magnesium sulfate.

4/ Less than 1/2 unit.

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TABLE 3
PRODUCTION AND SALES OF POTASH IN NEW MEXICO 1/

(Thousand metric tons and thousand dollars)

Period	Crude salts 2/ (mine production)		Marketable potassium salts				
			Production		Sold or used		
	Gross weight	K2O equivalent	Gross weight	K2O equivalent	Gross weight	K2O equivalent	Value 3/
1995							
January-June	6,560	834	1,230	578	1,270	599	114,000
July-December	6,710	840	1,240	582	1,060	502	95,300
Total	13,300	1,670	2,460	1,160	2,330	1,100	209,000
1996							
January-June	6,790	835	1,210	572	1,380	648	124,000
July-December	6,320	1,150	1,200	558	1,060	501	101,000
Total	13,100	1,980	2,400	1,130	2,430	1,150	225,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Sylvinite and langbeinite.
3/ F.o.b. mine.

TABLE 4
SALIENT U.S. SULFATE OF POTASH STATISTICS 1/ 2/

(Thousand metric tons of K2O equivalent and thousand dollars)

	1992	1993	1994	1995	1996
Production	243	251	252	295	W
Sales by producers	267	245	248	246	W
Value 3/	$87,900	$80,800	$75,700	$81,400 r/	W
Exports 4/	158	114	139	148 r/	144
Imports 4/	35	45	36	26 r/	31
Value 5/	$13,600	$17,300	$19,000	$10,900	$12,900
Consumption, apparent 6/	144	176	145	124 r/	W
Yearend producers stocks	34	40	44	93	W

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Excluding potassium magnesium sulfate.
2/ Data rounded to three significant digits.
3/ F.o.b. mine.
4/ Bureau of the Census.
5/ C.i.f. to U.S. port.
6/ Calculated from sales plus imports minus exports.

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TABLE 5
SALES OF NORTH AMERICAN POTASH, BY STATE OF DESTINATION 1/

(Metric tons of K2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	1995	1996	1995	1996
Alabama	101,000	98,200	214,000	230,000
Alaska	276	582	1,430	1,530
Arizona	4,890	6,020	523	707
Arkansas	79,700	80,700	1,120	1,150
California	79,600	116,000	8,980	12,200
Colorado	16,000	14,500	3,020	2,070
Connecticut	2,990	1,910	1,030	1,120
Delaware	23,700	22,800	47,700	49,100
Florida	179,000	194,000	2,330	5,390
Georgia	165,000	167,000	2,000	1,680
Hawaii	5,330	7,180	11	44
Idaho	37,800	39,500	1,020	1,140
Illinois	609,000	552,000	11,900	17,100
Indiana	380,000	284,000	3,610	3,780
Iowa	459,000	421,000	4,640	6,560
Kansas	54,200	53,300	4,490	4,510
Kentucky	135,000	132,000	800	1,200
Louisiana	154,000	124,000	3,640	4,020
Maine	4,910	6,910	392	756
Maryland	28,700	32,200	888	743
Massachusetts	6,200	3,830	548	661
Michigan	202,000	184,000	8,180	7,370
Minnesota	282,000	312,000	6,110	7,530
Mississippi	91,100	117,000	36,000	8,160
Missouri	247,000	208,000	3,900	7,370
Montana	17,200	17,600	115	103
Nebraska	36,400	42,500	1,500	1,720
Nevada	479	619	131	142
New Hampshire	854	641	64	76
New Jersey	4,750	5,190	683	1,340
New Mexico	6,830	6,740	19,900	22,400
New York	64,900	57,500	1,310	1,470
North Carolina	110,000	125,000	1,370	1,180
North Dakota	32,800	30,700	34	120
Ohio	424,000	334,000	72,100	73,500
Oklahoma	23,900	18,300	1,650	3,790
Oregon	38,000	37,300	1,720	1,740
Pennsylvania	54,300	57,400	4,250	12,600
Rhode Island	399	915	542	198
South Carolina	63,100	70,100	1,150	1,370
South Dakota	13,000	17,000	271	434
Tennessee	96,100	92,700	583	8,720
Texas	155,000	150,000	17,000	19,200
Utah	8,940	5,120	4,860	6,950
Vermont	4,880	5,030	127	234
Virginia	87,400	88,500	162	225
Washington	64,200	43,800	1,810	1,360
West Virginia	2,800	2,630	876	1,080
Wisconsin	216,000	215,000	56,300	75,900
Wyoming	2,500	5,030	725	588
Total	4,880,000	4,610,000	557,000	612,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Potash & Phosphate Institute.

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TABLE 6
SALES OF NORTH AMERICAN MURIATE OF POTASH
TO U.S. CUSTOMERS, BY GRADE 1/

(Thousand metric tons of K2O equivalent)

Grade	1995	1996
Agricultural:		
Standard	225	272
Coarse	2,300	1,940
Granular	1,680	1,700
Soluble	444	484
Total	4,650	4,400
Nonagricultural:		
Soluble	98	75
Other	454	525
Total	552	600
Grand total	5,200	5,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Potash & Phosphate Institute.

TABLE 7
PRICES 1/ OF U.S. POTASH, BY TYPE AND GRADE

(Dollars per metric ton of K2O equivalent)

	1995		1996	
Type and grade	January-June	July-December	January-June	July-December
Muriate, 60% K2O minimum:				
Standard	139.49 r/	136.49	131.82	136.31
Coarse	120.02 r/	138.47	126.50	144.40
Granular	142.67 r/	133.23	131.11	135.39
All muriate 2/	140.04 r/	134.66 r/	131.24	135.36
Sulfate, 50% K2O minimum	323.77	342.29	W	W

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Average prices, f.o.b. mine, based on sales.
2/ Excluding soluble and chemical muriates.

TABLE 8
U.S. EXPORTS OF POTASH, BY TYPE 1/

	Approximate average K2O content (percent)	Quantity (metric tons)	
		Product	K2O equivalent
1995			
Potassium chloride, all grades	61	297,000	181,000
Potassium sulfate	51	290,000	148,000
Potassium magnesium sulfate	22	339,000	74,600
Potassium nitrate	45	11,600	5,220
Total	XX	938,000	409,000
1996			
Potassium chloride, all grades	61	393,000	239,000
Potassium sulfate	51	283,000	144,000
Potassium magnesium sulfate	22	411,000	90,500
Potassium nitrate	45	14,300	6,430
Total	XX	1,100,000	481,000

XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 9
U.S. EXPORTS OF POTASH, BY COUNTRY 1/

(Metric tons of product)

Country	Potassium chloride		Potassium sulfate, all grades 2/		Potassium nitrate		Total	
	1995	1996	1995	1996	1995	1996	1995	1996
Argentina	3,880	1,980	9,610	17,800	--	--	13,500	19,800
Australia	3,030	165	8,070	115	40	36	11,100	316
Belgium	25,800	66	649	1,940	434	275	26,900	2,280
Brazil	25,900	59,800	15,400	7,380	3	--	41,200	67,100
Canada	4,960	11,800	62,900	75,600	4,610	4,730	72,500	92,200
Chile	48,200	26,400	22,300	39,400	--	--	70,600	65,700
China	--	--	130,000	91,800	--	--	130,000	91,800
Colombia	3,540	9,370	6,510	10,500	--	62	10,000	20,000
Costa Rica	24,200	28,000	39,200	39,500	--	--	63,400	67,500
Dominican Republic	19,800	35,800	5,200	6,400	7	19	25,000	42,200
Ecuador	5,700	24,700	3,600	4,450	737	17	10,000	29,100
France	--	16,500	16,700	9	--	--	16,700	16,500
Guatemala	9,720	7,620	8,310	3,000	--	--	18,000	10,600
Honduras	5,900	2,130	7,360	4,240	61	--	13,300	6,370
Italy	14,200	16,100	660	--	--	--	14,900	16,100
Japan	6,440	3,010	161,000	174,000	2	17	168,000	177,000
Korea, Republic of	2,590	1,380	6	21,600	279	--	2,880	23,000
Malaysia	--	--	9,700	94	880	2,010	10,600	2,100
Mexico	38,400	115,000	42,200	84,300	4,270	3,220	84,900	203,000
Peru	6,340	6,170	11,000	24,500	25	--	17,400	30,700
Philippines	17	--	459	35	--	--	476	35
Thailand	--	8	20,300	12,900	--	--	20,300	12,900
Venezuela	6,430	919	26,100	33,900	--	30	32,600	34,800
Zimbabwe	--	--	9,610	21,000	--	--	9,610	21,000
Other	42,000	25,700	11,700	20,000	243	3,880	54,000	49,500
Total	297,000	393,000	629,000	694,000	11,600	14,300	938,000	1,100,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes potassium magnesium sulfate.

Source: Bureau of the Census.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY TYPE 1/

	Approximate average K2O content (percent)	Quantity (metric tons)		Value (thousands)	
		Product	K2O equivalent e/	Customs	C.i.f.
1995:					
Potassium chloride	61	7,830,000	4,780,000	577,000	670,000
Potassium sulfate	51	51,800	26,400	9,530	10,900
Potassium nitrate	45	36,600	16,400	9,170	10,700
Potassium sodium nitrate mixture	14	38,600	5,400	6,180	6,870
Total	XX	7,960,000	4,820,000	602,000	698,000
1996:					
Potassium chloride	61	8,030,000	4,900,000	539,000	630,000
Potassium sulfate	51	60,400	30,800	11,300	12,900
Potassium nitrate	45	30,400	13,700	8,690	9,990
Potassium sodium nitrate mixture	14	21,900	3,070	3,430	3,930
Total	XX	8,140,000	4,940,000	563,000	657,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY COUNTRY 1/

Country	Potassium chloride (metric tons)		Potassium sulfate (metric tons)		Potassium nitrate (metric tons)		Potassium sodium nitrate (metric tons)		Total 1/ (metric tons)		Total value (thousands)			
											Customs		C.i.f.	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Belarus	93,600	--	--	--	--	--	--	--	93,600	--	$6,740	--	$8,030	--
Belgium	3,080	2,800	4,630	4,600	1	40	--	--	7,710	7,440	1,250	$1,180	1,480	$1,450
Canada	7,460,000	7,540,000	5,390	6,600	150	--	12,900	1,340	7,480,000	7,540,000	553,000	504,000	640,000	589,000
Chile	--	--	--	80	23,800	15,600	25,600	20,600	49,400	36,200	9,260	7,420	10,600	8,380
Denmark	--	--	3	--	2,060	1,470	18	--	2,090	1,470	616 r/	495	843 r/	658
Dominican Republic	--	--	--	160	102	--	--	--	102	160	48	53	52	59
Germany	3,410	5,120	39,800	48,700	137	275	--	--	43,400	54,100	7,010	9,320	8,180	10,700
Israel	54,000	33,900	--	--	9,760	12,500	--	--	63,700	46,400	8,540	7,360	9,860	8,370
Japan	4	--	1	28	518	440	--	--	523	468	180	177	216	195
Jordan	19,700	--	--	--	--	--	--	--	19,700	--	1,420	--	1,470	--
Latvia	16,300	--	--	--	--	--	--	--	16,300	--	1,180	--	1,520	--
Liberia	13,700	--	--	--	--	--	--	--	13,700	--	1,270	--	1,290	--
Mexico	--	--	756	1	--	--	21	--	777	1	54	4	56 r/	4
Netherlands	--	--	1,160	--	1	--	--	--	1,160	--	220	--	251	--
Poland	--	18,700	--	--	54	36	--	--	54	18,700	27	2,060	32	2,380
Russia	167,000	427,000	--	50	--	--	--	--	167,000	427,000	11,300	29,800	14,000	35,100
United Kingdom	170	1,310	--	--	--	--	--	--	170	1,310	169	295	195	340
Other	1	140	--	120	2	60	--	--	3	320	6	173	6	195
Total	7,830,000	8,030,000	51,800 r/	60,400	36,600	30,400	38,600 r/	21,900	7,960,000	8,140,000	602,000	563,000	698,000	657,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 12
MARKETABLE POTASH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons of K2O equivalent)

Country	1992	1993	1994	1995	1996 e/
Belarus	3,311	1,947	3,021	3,211	3,200
Brazil	85	173	242 r/	370 r/	375
Canada	7,270	6,836	8,037	8,855 r/	8,170
Chile e/ 3/	55	55	50	50	50
China e/	21	25	74	80	110
France	1,141	890	870	799 r/	800
Germany	3,461	2,861	3,286	3,280 e/	3,200
Israel	1,296	1,309	1,259	1,320 e/	1,320
Italy	86	20 e/	--	--	--
Jordan	794	822	930	1,070 e/	1,200
Russia	3,470	2,628	2,498	2,800 e/	2,800
Spain	594	661	684	650 e/	600
Ukraine	98	88 e/	168	110	100
United Kingdom	529	555	580	582 e/	580
United States	1,710	1,510	1,400	1,480	1,390 4/
Total	23,900	20,400	23,100	24,700	23,900

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 24, 1997.

3/ Data from Comisión Chilena del Cobre. This is the sum of potassium chloride production and exports of mixed sodium-potassium nitrates.

4/ Reported figure.

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PUMICE AND PUMICITE

By Wallace P. Bolen

For 1996, the amount of pumice sold or used by domestic producers increased nearly 16% compared with 1995. Pumice and pumicite apparent consumption in the United States increased about 12% in 1996 compared with that of 1995, according to the U.S. Geological Survey (USGS). Because imports declined for the first time in three years, the increase was strictly attributable to greater consumption of domestically produced pumice and pumicite. By volume, most imports were for construction-related uses with small but significant amounts used for abrasives and stonewashing. Greece remained the largest source for pumice imports, supplying over 92% of pumice imports. *(See table 1 .)*

Production

Pumice and pumicite sold or used by U.S. producers increased to 612,000 metric tons with a value of $14.8 million. The average price of pumice fell 80 cents per ton from $24.99 per metric ton to $24.19 per ton. Most of the price decrease resulted from increased consumption of the less expensive abrasive grades pumice. Oregon remained as the largest source of pumice followed in descending order by, Idaho, New Mexico, California, Arizona, and Kansas.

Domestic production data for pumice and pumicite were developed by the USGS from a voluntary survey of U.S. operations. Fourteen companies with 15 active operations contributed 100% of the quantity and value of sold and used as shown in table 1. Four of the companies, with four operations, did not respond to the 1995 survey. Sold and used data from these companies were estimated. The ten companies that responded contributed about 78% of the 612,000 tons reported in table 1.

Domestic producers were Tufflite Inc., Phoenix, AZ; California Industrial Minerals Co., Friant, CA; Glass Mountain Pumice Inc., Tulelake, CA; U.S. Pumice Co., Chatsworth, CA; Amcor Precast, Idaho Falls, ID; Hess Pumice Products, Malad City, ID; Producers Pumice, Meridian, ID; Calvert Corp., Norton, KS; Kansas Minerals Inc., Mankato, KS; Copar Pumice Co. Inc., Espanola, NM; Western Mobile New Mexico, Inc., Santa Fe, NM; Utility Block Co., Albuquerque, NM; Cascade Pumice Co., Bend, OR; and Central Oregon Pumice Co., Bend, OR.

Consumption

The amount of pumice sold or used by U.S. producers rose due to increased consumption in the abrasives, concrete, and laundries markets. Abrasive sales nearly quadrupled to 111,000 tons, from 31,000 tons in 1995. This spectacular increase was spurred on by rising foreign demand which prompted one producer to double its production capacity for some grades of abrasive pumice. Consumption for miscellaneous uses increased as well. Demand for stonewashing (or laundry) grade pumice unexpectedly increased in 1996 and domestic producers were able to supply this demand. Industry insiders speculated that commercial laundries' experiments with alternate materials including diatomite, perlite, and chemical treatments, had limited success and therefore laundries were returning to pumice. Additionally, imports of stonewashing grade pumice apparently decreased as well, although hard numbers were not available. The laundries continued to experience either disposal or environmental problems with most of the stonewashing aides.

The most important market for pumice remained building block, consuming 48% of the total pumice sold or used in the United States. However, the amount of pumice sold for building block dropped nearly 9%, from 320,000 tons to 292,000 tons. Other important uses, in descending order, were for abrasives (18%), horticulture and landscaping (11%), stonewashing laundries (8%), and concrete aggregate (7.5%). The remaining pumice and pumicite was used for absorbent, diluents, fill, and other unspecified uses. *(See table 2.)*

Foreign Trade

Pumice imports in 1996 dropped 9% compared with 1995 to 215,000 tons. Greece continued to be the largest source of imports although the amount of pumice imported from Greece fell 3.4% to 198,000 tons. Previous reports of imports from Zaire in 1994 and 1995 to the United States were incorrect as it was determined that the tonnage should have been assigned to Greece. Other major exporting countries to the United States were Ecuador, Italy, and Turkey. Besides these countries, 19 other countries exported pumice to the United States in 1996. *(See table 3.)*

Exports dropped to 13,000 tons with a value of $6.3 million. Receiving countries were led by Canada, 54%, followed by Japan, 11%; Surinam, 10%; and the United Kingdom, 9%. The remainder of exports went to 26 other countries on every continent except Antarctica.

World Review

The USGS estimates world pumice (and related materials) production at 11.1 million tons. Globally, Italy remained the dominant producer of pumice and pozzolan, with annual production around 5 million tons. Other leading countries in the

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production of pumice and related materials where Chile, Ethiopia, France, Germany, Greece, Spain, Turkey, and the United States. Besides these countries, 17 other countries produced pumice around the world. *(See table 4.)*

Outlook

Consumption of pumice and pumicite in 1997 is expected to remain at about the same levels as in 1996, as construction activity is expected to continue at a steady level in 1997. Trade should pickup in 1997, with both imports and exports exceeding 1996 levels.

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TABLE 1
SALIENT PUMICE AND PUMICITE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States: Sold and used by producers:					
Pumice and pumicite	481	469	490	529	612
Value (f.o.b. mine and/or mill)	$14,900	$12,000	$11,800	$13,200	$14,800
Average value per ton	$30.99	$25.68	$24.08	$24.99	$24.19
Exports e/	11	18	18	16	13
Imports for consumption	257	143	143	238	215
Apparent consumption 2/	727	594	615	728	814
World: Production, pumice and related volcanic materials	11,200 r/	11,700 r/	11,500 r/	11,000 r/	11,100 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Production plus imports, minus exports, plus adjustments for Government and industry stock changes.

TABLE 2
PUMICE AND PUMICITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

(Thousand metric tons and thousand dollars)

	1995		1996	
Use	Quantity	Value	Quantity	Value
Abrasives 2/	31	3,560	111	4,590
Building block (includes decorative)	320	3,400	292	4,250
Concrete admixture and aggregate	32	599	46	820
Horticulture and landscaping	69	1,680	66	1,910
Laundries	41	2,090	49	1,340
Other 3/	36	1,890	48	1,860
Total	529	13,200	612	14,800

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes cleaning and scouring compounds.

3/ Includes absorbent, diluents, fill, and other unspecified uses.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF PUMICE, BY CLASS AND COUNTRY 1/

(Thousand metric tons and thousand dollars)

	Crude or unmanufactured		Wholly or partly unmanufactured	
Country	Quantity	Value	Quantity	Value
1995:				
Ecuador	25	294	--	--
Greece 2/	205 r/	14,900 r/	--	--
Italy	(3/)	281	1	246
Mexico	(3/)	63	--	--
Turkey	7	894	--	--
Zaire	(4/)	(4/)	--	--
Other 5/	(3/)	17	(3/)	83
Total	237	16,400	1	329
1996:				
Ecuador	3	185	--	--
Greece 2/	198	13,400	--	--
Italy	(3/)	265	(3/)	158
Mexico	(3/)	31	(3/)	27
Turkey	14	1,920	(3/)	10
Other 6/	(3/)	151	(3/)	513
Total	215	16,000	(3/)	708

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The Journal of Commerce Port Import/Export Reporting Service data.

3/ Less than 1/2 unit.

4/ Revised to zero.

5/ Includes Austria, Canada, Germany, Guatemala, the Republic of Korea, Spain, Taiwan, and the United Kingdom.

6/ Includes Austria, Canada, China, France, Germany, Guatemala, Honduras, Iceland, Indonesia, Japan, the Republic of Korea, the Netherlands, New Zealand, Nicaragua, the Philippines, Spain, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

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TABLE 4
PUMICE AND RELATED MATERIALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina 4/	89,060	98,631 r/	114,082 r/	52,255 r/	60,000
Austria: Trass	7,493	9,102	5,620	6,000 e/	6,000
Burkina Faso e/	10,000	10,000	11,000	11,000	11,000
Cameroon: Pozzolan e/	130,000	130,000	130,000	130,000	130,000
Cape Verde: Pozzolan e/	53,000	25,000	5,000	5,000	1,000
Chile: Pozzolan	384,744	448,250	452,000 r/	450,000 e/	450,000
Costa Rica e/	8,000	8,000	8,000	8,000	8,000
Dominica: Pumice and volcanic ash e/	100,000	100,000	100,000	100,000	100,000
Ecuador	20,600	12,230	8,665 r/	9,000 r/ e/	9,000
Ethiopia	49,000 e/	40,000 e/	127,000 r/	360,000 r/	400,000
France: Pozzolan and lapilli	404,000	526,000	490,000 r/	427,000 r/	450,000
Germany: Pumice (marketable)	591,000 e/	647,000	504,000 r/	625,000 e/	600,000
Greece:					
Pumice	635,578 r/	600,000 r/ e/	635,470 r/	600,000 r/ e/	600,000
Pozzolan	644,785 r/	600,000 r/ e/	649,608 r/	600,000 r/ e/	600,000
Guadeloupe: Pumice e/	220,000	210,000	210,000	210,000	210,000
Guatemala: Pumice	6,591	6,300	6,000 e/	6,200 e/	6,300
Iceland e/	33,514 5/	45,000	23,000	30,000	25,000
Iran	330,016	185,000	200,000 e/	200,000 e/	200,000
Italy: e/					
Pumice and pumiceous lapilli	600,000	700,000	700,000	650,000	600,000
Pozzolan	4,400,000	4,500,000	4,500,000	4,000,000	4,000,000
Macedonia: Volcanic tuff e/	100,000	75,000	75,000	75,000	75,000
Martinique: Pumice e/	140,000	130,000	130,000	130,000	130,000
New Zealand	112,476	69,179	116,840 r/	77,054 r/	80,000
Serbia and Montenegro: Volcanic tuff	108,792	74,230	75,000 e/	75,000 e/	75,000
Slovenia: Volcanic tuff e/	50,000	40,000	40,000	40,000	40,000
Spain e/ 6/	800,000	700,000	700,000	600,000	600,000
Turkey	736,316	1,224,114	947,174 r/	1,000,000 r/ e/	1,000,000
United States (sold and used by producers)	481,000	469,000	490,000	529,000	612,000 5/
Total	11,200,000 r/	11,700,000 r/	11,500,000 r/	11,000,000 r/	11,100,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 29, 1997.

3/ Pumice and related volcanic materials are also produced in a number of other countries, including (but not limited to) Japan, Mexico, the former U.S.S.R., and Zaire; output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

4/ Unspecified volcanic materials produced mainly for use in construction products (includes pumice, perlite, pozzolan and toba).

5/ Reported figure.

6/ Includes Canary Islands.

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RARE EARTHS

By James B. Hedrick

The rare earths are a relatively abundant group of elements that range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements at 60 parts per million, to lutetium, the 61st most abundant element at 0.5 part per million. The rare earths were discovered in 1787 by Swedish Army Lieutenant Karl Axel Arrhenius when he collected the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine near the village of Ytterby, Sweden. With similar chemical structures, the rare-earth elements proved difficult to separate. It was not until 1794 that the first element, an impure yttrium oxide, was isolated from ytterbite by Finnish chemist Johann Gadolin. The elemental forms of rare earths are iron gray to silvery lustrous metals; typically soft, malleable, and ductile; and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798° C for cerium to 1,663° C for lutetium. The rare earths' unique properties are used in a wide variety of applications.

Domestic mine production of rare earths decreased in 1996. The domestic economy continued to improve, and inflation, based on the Bureau of Labor Statistics consumer price index, increased at the low rate of 3%. Estimated domestic apparent consumption increased again in 1996 because demand was strong for rare-earth compounds used in automotive catalytic converters, permanent magnets, and rechargeable rare-earth-nickel hydride batteries. Earnings by the major domestic processor also reportedly increased amid gains in sales. *(See table 1.)* Demand also increased for rare earths used in petroleum fluid cracking catalysts, while rare-earth phosphors for television, x-ray intensifying, and fluorescent and incandescent lighting remained stable. Yttrium was used primarily in lamp and cathode-ray tube phosphors, structural ceramics, and oxygen sensors.

The domestic use of scandium increased in 1996, but overall consumption remained small. Commercial demand increased as new applications entered the market. Most metal and compounds were sold for metallurgical research and analytical standards. Minor amounts were used in specialty lighting and semiconductors.

Legislation and Government Programs

The calendar year 1996 included parts of the U.S. Government fiscal years for 1996 and 1997. Public Law 104-106, the National Defense Authorization Act for Fiscal Year 1996, was not enacted until February 10, 1996, because of significant delays in the Congressional budget process and a Presidential veto. The National Defense Authorization Act for Fiscal Year 1997, Public Law 104-201, was enacted on September 23, 1996. All stocks of rare earths in the National Defense Stockpile (NDS) were previously sold; however, at yearend 1996 the NDS contained 455 metric tons (501 short tons) of unshipped rare earths contained in sodium sulfate.

Production

Domestic mine production data for rare earths are developed by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations entitled, "Rare Earths." The one mine to which a survey form was sent responded, representing 100% of domestic mine production. Mine production data from one source, which is typically withheld to avoid disclosing company proprietary data, was authorized for release by Molycorp, Inc. (bastnasite concentrate only).

The United States remained a major world producer of rare earths in 1996 with only one domestic mine in operation. Domestic production was entirely from Molycorp, a wholly owned subsidiary of Unocal Corp. Bastnasite, a rare-earth fluorocarbonate mineral, was mined by open pit methods at Mountain Pass, CA. Molycorp's mine was the leading producer of rare earths in the United States and second in the world. Mine production, as reported from company sources, decreased from the previous year's level of 22,200 tons of rare-earth oxide (REO) to 20,400 tons REO in 1996.

Refined lanthanides were produced by three companies in 1996. Molycorp produced refined compounds from bastnasite at its separation plant at Mountain Pass, CA.

Rhône-Poulenc Basic Chemicals Co. (RP) produced lanthanide compounds from rare-earth intermediate compounds at its facility at Freeport, TX. A new production unit was started at RP's Freeport site to produce rare-earth catalysts. The catalysts will be used in automobile emission-control catalytic converters. The catalyst is a mixture of cerium, praseodymium, lanthanum, yttrium, sodium, and zirconium (Industrial Minerals, 1996h). Grace Davison refined rare earths for petroleum fluid cracking catalysts from rare-earth chlorides and other rare-earth compounds at Chattanooga, TN.

Except for minor amounts of yttrium contained in domestically produced bastnasite concentrates, essentially all purified yttrium was derived from imported compounds.

Three scandium processors operated in 1996. High-purity products were available in various grades with scandium oxide produced up to 99.999% purity.

Sausville Chemical Co. refined scandium concentrates at its facilities in Garfield, NJ, to produce high-purity scandium oxide, fluoride, nitrate, chloride, and acetate. Joint-venture research

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partner Recovery Dynamics of Johnson City, TN, will locate its new refinery facility in Elizabethton, TN. The joint venture is expected to start scandium refining by yearend 1997 on a larger scale than previously available.

Boulder Scientific Co. processed scandium at its Mead, CO, operations. Boulder refined scandium primarily from imported oxides to produce high-purity scandium compounds, including diboride, carbide, chloride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium was also purified and processed from imported oxides at Aldrich-APL in Urbana, IL, to produce high-purity scandium oxide, fluoride, and hydrous and anhydrous chloride. Aldrich-APL also produced high-purity scandium metal.

Principal domestic producers of neodymium-iron-boron magnet alloys were Magnequench International, Inc., Anderson, IN; Neomet Corp., West Pittsburg, PA; and Rhône-Poulenc Basic Chemicals Co., Phoenix, AZ. Leading U.S. producers of rare-earth magnets were Magnequench International, Anderson, IN; Hitachi Magnetics, Edmore, MI; Crucible Materials, Elizabethtown, KY; and Ugimag, Valparaiso, IN.

Consumption

Statistics on domestic rare-earth consumption are developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths increased in 1996 compared with that of 1995. Domestic production of mischmetal, rare-earth silicide, and other rare-earth alloys in 1996 was essentially the same as that in 1995, while consumption of the alloys increased. Shipments of mixed rare-earth alloys declined 13%. Consumption of mixed rare-earth compounds showed a gain as demand continued for mixed intermediates for petroleum fluid cracking catalysts and automotive catalytic converters. Domestic shipments of mixed compounds decreased 56% in 1996.

The approximate distribution of rare earths by use, based on information supplied by U.S. rare-earth refiners, selected consumers, and analysis of import data, was as follows: automotive catalytic converters, 46%; petroleum refining catalysts, 25%; permanent magnets, 12%; glass polishing and ceramics, 7%; metallurgical additives and alloys, 7%; rare-earth phosphors for lighting, televisions, computer monitors, radar, and x-ray intensifying film, 3%; and miscellaneous, less than 1%.

Yttrium consumption was estimated by the USGS commodity specialist at 207 tons for 1996, a decrease of 158 tons from that of 1995. The approximate distribution of yttrium by end use, based on analysis of import data, was as follows: lamp and cathode-ray tube (CRT) phosphors, 98%; and oxygen sensors and miscellaneous, 2%. Yttrium compounds were sourced from China, 80.8%, and Japan, 19.2%.

Tariffs

U.S. tariff rates, specific to the rare earths, including scandium and yttrium, were changed slightly in 1996. Revisions to the Harmonized Tariff duty for cerium compounds (2846.10.00) decreased for most-favored-nation status from 6.5% ad valorem to 6.2% ad valorem. A tariff of 3 cents per kilogram was added to "mineral substances, not elsewhere specified or included" (2530.90.0050), which includes rare-earth metal ores, excluding monazite. Special rare-earth tariffs for Canada and Mexico were the result of Presidential Proclamation 6641, implementing the North American Free Trade Agreement (NAFTA), effective January 1, 1994.

Under the agreement, Mexico's tariff for "rare-earth metals, including yttrium and scandium, whether intermixed or interalloyed" (2805.30.00) decreased from 2% ad valorem to 1% ad valorem. Mexico's tariff for "aluminum alloys, other" (7601.20.9090), which would include scandium-aluminum alloys, decreased from 1.6% ad valorem to 1.2% ad valorem. For all other rare-earth Harmonized Tariff Schedule classifications, Canada and Mexico were granted free status. Tariff rates for most other foreign countries were negotiated under the Generalized Agreement on Tariffs and Trade (GATT) Uruguay Round of Multilateral Trade Negotiation. New staged rate schedules taking effect January 1, 1996, were negotiated at the GATT Uruguay Round of negotiations in 1994. U.S. tariff rates for rare earths are listed in the Harmonized Tariff Schedule of the United States (1996), publication 2937, with supplement, and the Harmonized Tariff Schedule of the United States (1997), publication 3001, as compiled by the United States International Trade Commission. U.S. tariffs are available in Publication 3001 from the U.S. Government Printing Office under document serial number 949-013-00000-6 File Code 1A.

Stocks

U.S. Government stocks of rare earths in the National Defense Stockpile remained at 455 tons throughout 1996. Rare-earth stocks held in the stockpile were contained in sodium sulfate and were inventoried on a contained-REO basis. All NDS stocks of rare earths were previously sold and were being held for shipment.

Prices

Rare-earth prices were mixed in 1996. Domestic prices for cerium were unchanged while neodymium prices decreased slightly. Prices decreased slightly for dysprosium, erbium, gadolinium, holmium, and lutetium, while most other rare-earth oxide prices remained unchanged. The following prices were estimated by the USGS specialist based on domestic trade data from various sources. The price of rare-earth chloride in 1996 was $2.60 per kilogram, while cerium concentrate prices were $27.14 per kilogram. All rare-earth prices remained nominal and subject to change without notice. Competitive pricing policies remained in effect with prices for most rare-earth products quoted on a daily basis.

The estimated market price for bastnasite concentrate was $3.91 per kilogram. The price range of Australian monazite

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(minimum 55% rare-earth oxide including thoria, free-on-board/free into container depot), as quoted in Australian dollars (A$), remained unchanged at the previous years range of A$300 to A$350 per ton. Changes in the United States-Australia foreign exchange rate in 1996, resulting from a weaker U.S. dollar on world markets, caused the U.S. dollar exchange rate to be down $0.07 against the Australian dollar at yearend. The U.S. price range, converted from Australian dollars, increased slightly to US$244 to US$285 per ton at yearend 1996, compared with US$222 to US$259 per ton at yearend 1995 (Metal Bulletin, 1995, 1996). Prices for monazite remained depressed because several principal world rare-earth processors continued to process only thorium-free feed materials.

The nominal price for basic neodymium-iron-boron alloy, compiled by the author from several U.S. producers, was unchanged from 1995's price of $28.43 per kilogram ($12.90 per pound), free-on-board (f.o.b.) shipping point, 1,000-pound minimum. Most alloy was sold with additions of cobalt (up to 15%, typically 4% to 6%) or dysprosium (up to 3%). The cost of the additions was based on market pricing; with the average cobalt price decreasing in 1996 to $56.22 per kilogram (average $25.50 per pound), the cost would be about $0.56 for each percent addition per kilogram ($0.26 for each percent addition per pound).

Standard-grade domestic mischmetal was priced slightly lower than the previous year at $9.50 per kilogram.

Rhône-Poulenc quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 1996, as shown in table 2. *(See table 2)*

No published prices for scandium oxide in kilogram quantities were available. Yearend 1996 nominal prices for scandium oxide per kilogram were compiled by the author from information from several domestic suppliers and processors. Prices decreased slightly from those of the previous year for most grades and were listed as follows: 99% purity, $1,400; 99.9% purity, $2,900; 99.99% purity, $4,400; and 99.999% purity, $6,750.

Scandium metal prices for 1996, as listed by the Johnson Matthey Alfa AESAR catalog, were unchanged from those in 1995 as follows: 99.99% REO purity, lump, sublimed dendritic, ampouled under argon, $169 per gram; 99.9% REO purity, <250-micron powder, ampouled under argon, $559 per 2 grams; and 99.9% purity, lump, sublimed dendritic lump, ampouled under argon, $442 per 2 grams; 99.9% REO purity, foil, 0.025 millimeter thick, ampouled under argon, 25 millimeters by 25 millimeters, $95 per item (Alfa AESAR, 1995).

Scandium compound prices for 1996, as listed by Aldrich Chemical Co., were as follows: scandium acetate hydrate 99.9% purity, $42.30 per gram; scandium chloride hydrate $99.99% purity, $56.90 per gram; scandium nitrate hydrate 99.9% purity, $54.80; and scandium sulfate pentahydrate 99.9% purity, $60.05 per gram. Prices for standard solutions for calibrating analytical equipment were $21.85 per 100 milliliters of scandium atomic absorption standard solution and $338.15 per 100 milliliters of scandium plasma standard solution (Aldrich, 1996).

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of the oxide while higher purity distilled scandium metal have averaged about five times the cost.

Foreign Trade

Exports and imports of rare earths increased in 1996. U.S. exports totaled 13,500 kilograms valued at $79 million, a 23% increase in quantity and 18% increase in value. Imports totaled 23,800 kilograms gross weight valued at $139 million, a 40% increase in quantity and nearly 15% increase in value compared with that of 1995.

Exports of rare earths increased in three out of four trade categories in 1996. U.S. exports are shown in table 3. The United States exported 208,000 kilograms of rare-earth metals, a 44% decrease from that of 1995, valued at $4.5 million. Principal destinations in descending order were Japan, France, the United Kingdom, and the Republic of Korea. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, increased 19% to 6,100,000 kilograms valued at $37.9 million. Major destinations were the Republic of Korea, Singapore, Germany, and Taiwan.

Exports of inorganic and organic rare-earth compounds increased from 1,550,000 kilograms in 1995 to 2,210,000 kilograms in 1996, while the value of the shipments increased 7% to $13.4 million. Shipments, in descending order of quantity, were to Brazil, Colombia, Canada, and Japan.

U.S. exports of ferrocerium and other pyrophoric alloys increased from 3,910,000 kilograms to 4,970,000 kilograms valued at $21.1 million. Principal destinations were Jordan, Canada, Germany, and Hong Kong.

The approximate distribution of imports based on analysis of Journal of Commerce data was as follows: automotive catalytic converters, 37%; petroleum refining catalysts, 16%; phosphors for lighting, televisions, computer monitors, radar, and x-ray intensifying film, 4%; metallurgical additives and alloys, 9%; permanent magnets, 15%; glass polishing and ceramics, 17%; ferrocerium and pyrophoric alloys, 2%; and miscellaneous, less than 1%.

Imports of compounds and alloys increased for five out of seven categories. U.S. imports are shown in table 4. China and France dominated the import market, especially for mixed and individual rare-earth compounds. *(See table 4)*

Cerium compounds accounted for 4,760,000 kilograms of imports valued at $30 million. The quantity of cerium compounds imported increased 16% due to continued demand for automotive exhaust catalysts. China was the major supplier for the second year in a row.

Imports of yttrium compounds containing between 19 weight-percent and 85 weight-percent oxide equivalent (yttrium concentrate) increased 37% in 1996. France was the leading supplier of yttrium compounds in this category.

Individual rare-earth compounds, excluding cerium compounds, accounted for the major share of rare-earth imports.

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Imports increased 76% in 1996 to 15,300,000 kilograms valued at $67.6 million. The major sources of individual rare-earth compounds were China and France with the value of the imports increasing 19%.

Imports of mixtures of rare-earth oxides, other than cerium oxide, increased almost 30% to 879,000 kilograms valued at $21.9 million. Principal sources in descending order were China, Japan, and Austria. Imports of rare-earth metals and alloys into the United States totaled 357,000 kilograms in 1996, a 53% decrease from the 1995 level. Valued at $3.7 million, the principal rare-earth metal sources were China and the United Kingdom. Metal imports decreased as demand for permanent magnet alloys was met primarily from domestic supplies.

Imports of rare-earth chlorides fell 14.3% in 1996 to 2,330,000 kilograms valued at $12.4 million. Supplies of rare-earth chloride came primarily from India, China, and Japan. Rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts. Imports of ferrocerium and pyrophoric alloys increased 36% to 120,000 kilograms valued at $1.98 million. Principal suppliers in descending order were France, Austria, and Brazil.

World Review

China, India, and the United States were major sources of rare-earth chlorides, nitrates, and other concentrates and compounds. Thorium-free intermediate compounds were still in demand as refinery feed as industrial consumers expressed concerns with radioactive thorium's potential liabilities, the costs of complying with environmental monitoring and regulations, and escalating costs at approved waste disposal sites. Demand for rare earths increased in Asia, Europe, and the United States as most world economies continued to improve.

World reserves of rare earths were estimated by the USGS at 100 million tons of contained REO. China has the largest share of world reserves with 43%.

Australia.—BHP Titanium Minerals Pty. Ltd. neared completion of its Beenup heavy-mineral sands mine. The $200 million project, announced in December 1994, was expected to begin production in early 1997. The mining and ilmenite smelting project was expected to employ 120 people (Department of Resource Development, 1996).

Consolidated Rutile Ltd. (CRL) relocated its dredge and floating wet concentrator from its depleted Bayside location to its Ibis-Alpha deposit on North Stradbroke Island, Queensland. During the relocation CRL, invested A$21 million to upgrade the concentrator to process 3,000 tons of mineral sands per hour, including all relocation and construction costs. Mine life of the Ibis-Alpha deposit is expected to be 9 years (Industrial Minerals, 1996g).

Brazil.—Decommissioning of the São Paulo rare-earth separation plant, which began in 1992, continued as Indústrias Nucleares do Brazil SA (INB) cleaned up natural radioactivity associated with thorium byproduct and waste. A new pilot separation plant at Buena, Rio de Janeiro, produced oxides of cerium, lanthanum, praseodymium, neodymium, samarium, and a europium-gadolinium concentrate from rare-earth chloride. A full-scale plant at Buena is scheduled for completion by yearend 1997 at a cost of $7 million. Feed for the new rare-earth plant, which is slated to produce 1,560 tons of rare-earth chloride per year, is from INB's monazite-bearing mine at Buena Norte, Rio de Janeiro (Industrial Minerals, 1996a).

Canada.—Ming Financial Corp. (Vancouver) and Iron Ore Co. of Canada (Montreal) signed an agreement to develop the Strange Lake rare-earth deposit on the border of Quebec and Labrador. Ming Financial will reportedly earn an interest in the deposit and ownership rights based on funding feasibility and development of the site (Victoria Times-Colonist, 1996). The deposit is unique in its mineralogy. The Strange Lake deposit contains 55 million tons of ore grading 3% zirconium oxide, 0.38% yttrium oxide, 0.29% niobium oxide, 0.076% beryllium oxide, and additional rare-earth oxides. The ore at Strange Lake is contained in an alkalic granitic complex of Precambrian age. The principal ore minerals are pyrochlore, gittinsite, and gadolinite (Bish Chanda, Iron Ore Company of Canada, written commun., 1983).

China.—A new rare-earth refining plant started production in July in Chenyang, Liaoning Province. Operated by Xingguang North Rare Earths Materials Co. Ltd., the plant had a capacity of 2,000 tons per year cerium oxide and cerium chloride.

Panxi Rare Earth Co. Ltd. of Xichang City, Sichuan Province, began processing bastnasite at its new plant to process 2,000 tons per year of bastnasite into lanthanum-lanthanide chloride, cerium carbonate, and cerium chloride (Industrial Minerals, 1996e).

Advanced Materials Resources Ltd. (AMR) of Toronto, Canada, announced plans to increase cerium carbonate production at its Zibo refinery in Shandong Province, China. The expansion of 960 tons per year will be added to existing capacity at Zibo of 750 tons per year. AMR continued to seek Chinese Government approval to install a refining plant at the Mianning rare-earth carbonatite, presently mined by the Mianning County Mining Co., Sichuan Province (Industrial Minerals, 1996b).

France.—Rhône-Poulenc SA (France) and Navistar International Corp. (U.S.) announced a joint venture to develop technology to reduce diesel emissions using cerium. The companies reported reduced emissions using a Navistar diesel engine and Rhône-Poulenc's cerium additive that exceeds the U.S. Government's emission standard for the year 2004. The additive was used in standard-grade diesel fuel to reduce both particulate and nitrogen oxide emissions (Chemical Market Reporter, 1997).

Mozambique.—BHP Minerals Ltd. (Australia) and Kenmare Resources PLC (Ireland) formed a joint venture to explore and possibly develop the Congolone coastal mineral sands deposit northeast of Angoche (Industrial Minerals, 1996d). According to Kenmare, the heavy-mineral sands deposit contains 6.5% ilmenite, 0.2% rutile, 0.4% zircon, 0.1% monazite, and 0.6% magnetite (Kenmare Resources PLC, 1988). Reserves at

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Congolone were stated at 166.8 million tons of ore with an average grade of 3.25% heavy minerals (Mining Journal, 1989).

Gencor Ltd. and Edlow Resources, joint venture, TiGen, completed its prefeasibility study of heavy-mineral sands deposit near Moebase in northern Mozambique (Gencor Ltd., 1996). A drilling program of 30,000 meters delineated a resource of 1.3 billion tons of ore containing 3.8% heavy minerals, including monazite (U.S. State Department, 1997).

At Quelemane, also in northern Mozambique, a heavy-mineral sands deposit containing resources of 520 million tons of ore grading 4.5% heavy minerals was discovered. Genbique, a wholly owned exploration license holding company of Gencor Ltd., holds the exploration licenses at both the Moebase and Quelemane deposits (U.S. State Department, 1997).

South Africa.—Rare Earth Extraction Co. (Rareco) received approval to begin mining monazite at the Steentampskraal deposit north of Vanrhynsdorp, Cape Province. The Steentampskraal deposit was previously mined for its monazite. Production was expected to begin in 1998 at a rate of 24,000 tons per year. Mine life of the deposit is estimated to be 10 years at the planned rate. A rare-earth processing plant to be constructed at the site to produce 6,000 tons per year rare-earth chloride was expected to cost R$15 million. In a second phase of construction, Rareco expected to build a cerium refining plant to produce cerium carbonate for the automotive catalytic converter market (Industrial Minerals, 1996c).

Vietnam.—Westralian Sands Ltd. (WSL) (Australia) announced that it was withdrawing from its joint-venture heavy-mineral sands project, Austinh Ltd. The joint venture between WSL (60%), Meteco-Ha Tinh Mining Company (Vietnam) (30%), and Mideco—part of the Ministry of Industry (Vietnam) (10%) was involved in disputes throughout 1995 over Austinh's alleged violation of WSL's exclusive export rights. Two of the joint-venture partners, Meteco-Ha Tinh and Mideco then reportedly charged WSL for apparent misappropriation of funds and illegal imports of a processing plant and equipment, with the subsequent impounding of 41 containers of heavy minerals at Haiphong Port. WSL relinquished its marketing rights at the beginning of 1996 and by May had its foreign joint venture license revoked (Industrial Minerals, 1996f).

Three bastnasite-bearing deposits are reportedly located in the Phong Tho district of Lai Chau Province. Located near north Nam Xe, south Nam Xe, and Dong Pao, proven and probable reserves total 9.38 million tons of REO at an unspecified grade. The Vietnamese Government announced it had signed an agreement with LG Metal Group (Republic of Korea) to explore and develop the Dong Pao rare-earth deposit (Industrial Minerals, 1996f).

Outlook

Rare-earth usage in the United States and the rest of the world continues to grow in volume and diversity. The U.S. economy continued to improve in 1996 with inflation staying at a low rate. Consumption of rare earths increased substantially in most applications. Rare-earth markets are expected to continue to use greater amounts of higher purity mixed and separated products. Strong demand is expected to continue for rare earths used in automotive catalytic converters and permanent magnets, a trend that is expected to continue into the next decade. Future growth is forecast for rare earths in magnetic refrigeration, rechargeable nickel hydride batteries, fiber optics, and medical applications, including magnetic resonance imaging (MRI) contrast agents and dental and surgical lasers.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several world-class rare-earth deposits in Australia and China have yet to be developed because world demand is currently being satisfied by existing production. Coupled with the likelihood that new deposits will continue to be located, world resources should be adequate to fulfill demand for the foreseeable future.

Domestic companies have shifted away from radioactive-bearing rare-earth ores. This trend has had a negative impact on monazite-producing mineral sands operations worldwide. Future long-term demand for monazite, however, is expected to increase due to its abundant supply and recovery as a low-cost byproduct. The cost and space to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

Domestic demand in 1997 is expected to exhibit moderation after the strong growth seen in 1995 and 1996. World markets are expected to continue to be very competitive based on lower wages and fewer environmental and permitting requirements. China and the United States are expected to remain significant rare-earth suppliers, while the future economic restructuring of Eastern Europe and Asia has a large potential for both new sources and new consumers.

The long-term outlook is for an increasingly competitive and diverse group of rare-earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry continues to grow. It is likely that new applications will continue to be discovered and developed.

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TABLE 1
SALIENT U.S. RARE-EARTH STATISTICS 1/

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

	1992	1993	1994	1995	1996
Production of rare-earth concentrates 2/	20,700	17,800	20,700	22,200	20,400
Exports:					
Cerium compounds	1,940	1,620	4,460	5,120	6,100
Rare-earth metals, scandium, and yttrium	44	194	329	444	250
Ores and concentrates	--	--	--	--	2
Rare-earth compounds, organic or inorganic	1,310	1,090	2,420	1,550	2,210
Ferrocerium and pyrophoric alloys	2,430	4,270	3,020	3,470	4,420
Imports for consumption: e/					
Monazite	--	--	--	40 r/	101
Metals, alloys, oxides, compounds	5,330	6,670	7,840	14,100	18,700
Stocks, producers and processors, yearend	W	W	W	W	W
Consumption, apparent e/	21,400	17,000	17,800	W	W
Prices, yearend, dollars per kilogram:					
Bastnasite concentrate, REO basis	$2.87	$2.87	$2.87	$2.87	$2.87
Monazite concentrate, REO basis	$0.41	$0.40	$0.46	$0.44	$0.48
Mischmetal, metal basis 3/	$12.68	$12.68	$12.68	$9.50	$8.75
Employment, mine and mill 4/	372	352	NA	NA	NA
Net import reliance 5/ as a percent of apparent consumption	33	(6/)	(6/)	(7/)	(7/)

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits, except prices.

2/ Comprises only the rare earths derived from bastnasite as obtained from Molycorp, Inc., company representative.

3/ Source: Elements--Rare Earths, Specialty Metals and Applied Technology.

4/ Employment at a rare-earth mine in California and at a mineral sands operation in Florida. The latter mine produced monazite as a byproduct and employees were not assigned to specific commodities. The mineral sands operation in Florida ceased recovery of monazite at the end of 1994.

5/ Imports minus exports plus adjustments for Government and industry stock changes.

6/ Net exporter.

7/ Net importer.

TABLE 2
RHÔNE-POULENC RARE-EARTH OXIDE PRICES IN 1996

Product (oxide)	Percent purity	Standard package quantity (kilograms)	Price per kilogram
Cerium	95.00	25	$19.00
Cerium	99.50	25	23.00
Dysprosium	95.00	20	65.00
Erbium	96.00	20	150.00
Europium	99.99	10	700.00
Gadolinium	99.99	50	115.00
Holmium	99.90	10	485.00
Lanthanum	99.99	25	23.00
Lutetium	99.99	2	4,500.00
Neodymium	95.00	20	22.00
Praseodymium	96.00	20	32.00
Samarium	96.00	25	75.00
Terbium	99.90	5	685.00
Thulium	99.90	5	3,600.00
Ytterbium	99.00	10	230.00
Yttrium	99.99	50	85.00

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TABLE 3
U.S. EXPORTS OF RARE-EARTHS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Cerium compounds: (2846.10.0000)				
Brazil	25,200	$207,000	36,200	$515,000
Canada	499,000	5,950,000	447,000	4,740,000
Egypt	36,000	221,000	72,000	249,000
France	9,730	55,200	84,200	269,000
Germany	78,200	573,000	570,000	3,810,000
Hong Kong	51,600	394,000	20,700	173,000
India	17,500	96,100	140,000	521,000
Japan	492,000	6,630,000	441,000	4,950,000
Korea, Republic of	1,660,000	8,600,000	2,210,000	11,800,000
Malaysia	218,000	4,610,000	494,000	3,960,000
Mexico	33,900	267,000	54,400	450,000
Singapore	1,490,000	5,380,000	830,000	2,630,000
Taiwan	373,000	1,500,000	551,000	2,250,000
United Kingdom	10,500	278,000	25,900	475,000
Other	118,000 r/	743,000 r/	120,000	1,140,000
Total	5,120,000	35,500,000	6,100,000	37,900,000
Rare-earth compounds: (2846.90.0000)				
Austria	6,510	147,000	4,370	103,000
Brazil	561,000	1,370,000	724,000	1,750,000
Canada	230,000	814,000	378,000	1,320,000
Chile	1,810	382,000	--	--
China	332,000	676,000	577	21,800
Colombia	--	--	397,000	422,000
France	32,400	345,000	209,000	840,000
Germany	52,200	1,960,000	62,000	2,090,000
Hong Kong	2,160	415,000	1,130	61,300
Japan	151,000	2,600,000	226,000	4,220,000
Korea, Republic of	18,500	1,110,000	17,000	1,080,000
Mexico	4,390	23,900	22,100	153,000
Taiwan	104,000	1,640,000	47,400	1,470,000
United Kingdom	15,400	638,000	60,000	747,000
Other	35,000 r/	1,280,000 r/	57,600	1,190,000
Total	1,550,000	13,400,000	2,210,000	15,500,000
Rare-earth metals, including scandium and yttrium: (2805.30.0000)				
Bahamas, The	18,300	26,600	--	--
Canada	60,500	386,000	9,510	61,300
China	37,200	20,000	2,350	6,130
France	40,700	83,200	39,400	118,000
Germany	2,360	106,000	1,460	50,800
Hungary	895	43,600	1,950	58,300
Indonesia	17,600	62,500	150	9,980
Japan	72,400	1,320,000	60,300	1,740,000
Korea, Republic of	1,920	145,000	15,000	320,000
Netherlands	5,490	171,000	--	--
Taiwan	79,800	123,000	292	46,900
United Kingdom	28,300	1,060,000	27,800	950,000
Other	4,110 r/	140,000 r/	46,400	917,000
Total	370,000	3,690,000	208,000	4,540,000

See footnotes at end of table.

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TABLE 3--Continued
U.S. EXPORTS OF RARE-EARTHS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Ferrocerium and other pyrophoric alloys: (3606.90.0000)				
Australia	119,000	$264,000	57,500	$232,000
Barbados	40,700	46,900	15,400	18,200
Canada	1,040,000	2,110,000	1,190,000	1,910,000
France	83,300	500,000	87,700	467,000
Germany	452,000	2,090,000	624,000	1,900,000
Greece	91,500	102,000	24,200	106,000
Hong Kong	194,000	789,000	210,000	753,000
India	24,700	207,000	363	7,810
Italy	5,230	291,000	14,300	215,000
Japan	62,900	1,550,000	112,000	2,100,000
Jordan	--	--	1,240,000	4,170,000
Korea, Republic of	13,900	148,000	110,000	475,000
Kuwait	63,100	103,000	170,000	89,700
Mexico	137,000	504,000	140,000	1,610,000
Netherlands	22,100	326,000	12,600	243,000
New Zealand	55,100	98,200	53,700	95,600
Peru	495,000	378,000	20,000	117,000
Philippines	23,000	28,600	76,900	498,000
Saudi Arabia	101,000	396,000	29,200	666,000
Singapore	83,800	270,000	156,000	505,000
Sweden	1,580	457,000	2,500	85,400
Taiwan	105,000	197,000	36,700	105,000
Thailand	29,600	381,000	14,700	45,500
United Arab Emirates	208,000	335,000	140,000	257,000
United Kingdom	101,000	417,000	76,900	1,820,000
Other	352,000	2,220,000 r/	366,000	2,580,000
Total	3,910,000	14,200,000	4,970,000	21,100,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, and oxalates: (2846.10.0000)				
Austria	33,200	$406,000	28,300	$353,000
China	2,480,000	13,300,000	4,040,000	21,300,000
France	1,440,000	8,810,000	553,000	6,150,000
Germany	21,000	362,000	837	46,400
Japan	99,100	2,280,000	79,200	1,720,000
Russia	22,100	158,000	9,080	74,400
United Kingdom	302	6,590	42,200	393,000
Other	478	14,300	--	--
Total	4,090,000	25,400,000	4,760,000	30,000,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent: (2846.90.4000)				
Austria	1,200	43,400	--	--
China	9,810	315,000	9,060	313,000
France	3,100	162,000	22,300	426,000
Germany	658	82,100	230	33,600
Japan	120	7,930	410	31,500
Russia	105	1,850	5,630	110,000
Switzerland	2,000	78,900	--	--
Taiwan	400	11,500	2,300	37,900
United Kingdom	13,400	285,000	2,250	72,900
Other	--	--	16	3,960
Total	30,800	988,000	42,200	1,030,000

See footnotes at end of table.

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TABLE 4 --Continued
U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY 1/

Country	1995 Quantity (kilograms)	1995 Value	1996 Quantity (kilograms)	1996 Value
Rare-earth compounds, including oxides, hydroxides, nitrates, and other compounds except chlorides: (2846.90.5000)				
China	5,380,000	14,100,000	11,200,000	19,900,000
France	2,930,000	23,600,000	3,490,000	27,000,000
Germany	14,100	971,000	732	162,000
Japan	222,000	9,630,000	334,000	12,100,000
Norway	5,210	2,990,000	534	97,500
Russia	19,900	381,000	15,700	566,000
United Kingdom	72,500	4,680,000	225,000	7,230,000
Other	19,300 r/	580,000 r/	35,900	480,000
Total	8,670,000	56,900,000	15,300,000	67,600,000
Mixtures of rare-earth oxide except cerium oxide: (2846.90.2010)				
Austria	21,800	812,000	15,700	979,000
China	524,000	8,850,000	810,000	14,500,000
France	70,900	4,120,000	15,400	973,000
Germany	--	--	4,630	306,000
Hong Kong	1,100	258,000	350	137,000
Japan	11,500	1,940,000	28,100	4,770,000
United Kingdom	40,600	574,000	2,940	115,000
Other	7,550 r/	122,000 r/	1,260	92,000
Total	678,000	16,700,000	879,000	21,900,000
Rare-earth metals, whether intermixed or alloyed: (2805.30.0000)				
Austria	17,600	$156,000	--	--
Belgium	33,400	288,000	2,780	84,200
China	593,000	4,380,000	342,000	2,690,000
Kazakstan	14,000	70,500	--	--
Russia	5,540	267,000	5,370	335,000
United Kingdom	84,400	2,360,000	6,250	507,000
Other	6,050 r/	148,000 r/	590	84,800
Total	754,000	7,670,000	357,000	3,710,000
Mixtures of rare-earth chlorides, except cerium chloride: (2846.90.2050)				
Belgium	19,700	232,000	2,920	42,500
China	325,000	4,330,000	329,000	4,950,000
Estonia	67,600	664,000	20,000	328,000
France	4,910	366,000	48	34,700
Germany	50	35,700	22,500	633,000
India	2,160,000	2,250,000	1,780,000	2,490,000
Japan	56,000	3,320,000	80,100	3,200,000
Russia	18,100	353,000	50,300	317,000
United Kingdom	64,600	756,000	44,100	335,000
Other	1,520 r/	72,500 r/	743	31,600
Total	2,720,000	12,400,000	2,330,000	12,400,000
Ferrocerium and other pyrophoric alloys: (3606.90.3000)				
Austria	6,740	180,000	6,320	157,000
Belgium	2,670	51,300	--	--
Brazil	4,500	77,900	6,000	121,000
France	72,800	1,090,000	105,000	1,650,000
Netherlands	1,080	23,000	1,620	34,600
Other	454	18,100	1,740	22,500
Total	88,300	1,440,000	120,000	1,980,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 5
RARE EARTHS: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of rare-earth oxide equivalent)

Country 3/	1992	1993	1994	1995	1996 e/
Australia e/	3,300	1,650	--	110 r/	--
Brazil	396	270 r/	256 r/	103 r/	200
China e/	21,300	22,100	30,700 r/	48,000 r/	55,000
India e/	2,200	2,500	2,500	2,700	2,700
Malaysia	427	224	234	448	340 4/
South Africa e/	240	240	72 4/	-- 4/	--
Sri Lanka e/	110	110	120	120	120
Thailand	89	220	57	--	--
U.S.S.R. e/ 5/	8,000	7,000	6,000	6,000	6,000
United States 6/	20,700	17,800	20,700	22,200	20,400 4/
Zaire e/	28	11	11	5 r/	5
Total	56,800	52,100 r/	60,600 r/	79,700 r/	84,800

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 3, 1997.

3/ In addition to the countries listed, rare-earth minerals are believed to be produced in Indonesia, Mozambique, North Korea, and Vietnam, but information is inadequate to formulate reliable estimates.

4/ Reported figure.

5/ Dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries.

6/ Comprises only the rare earths derived from bastnasite as reported from company sources.

TABLE 6
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1992	1993	1994	1995	1996 e/
Australia e/	6,000	3,000	--	--	--
Brazil e/	1,400 4/	1,400	1,400	1,400	1,400
China e/	1,800	1,800	1,800	1,800	1,800
India e/	4,000	4,600	4,600	5,000	5,000
Malaysia	777	407	425	814	450
South Africa e/ 5/	430	430	131	--	--
Sri Lanka e/	200	200	200	200	200
Thailand	89	220	57	60	--
United States	W	W	W	--	--
Zaire e/	50	20	20	20 r/	10
Total	14,700	12,100	8,630	9,230 r/	8,860

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

1/ Table includes data available through May 28, 1997.

2/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Indonesia, North Korea, the Republic of Korea, Nigeria, and the former U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

4/ Reported figure.

5/ Monazite occurs in association with titanium sands mining but is not necessarily recovered.

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RECYCLING—METALS

By Staff, Minerals Information Team

Introduction[1]

Materials consumed by society include reusable resources, such as metals. The supply of metals is ultimately fixed by nature, but human ingenuity plays a role in determining quantity of supply by developing economic processes for the recovery of primary metal (i.e., from the earth) and secondary metal (i.e., from the use process stream). The reusable nature of metals contributes to the sustainability of their use.

Recycling, a significant factor in the supply of many of the key metals used in our society, provides environmental benefits in terms of energy savings, reduced volumes of waste, and reduced emissions. These reductions, in turn, result in reduced disturbance of land, reduced pollution, and reduced energy use. Table 1 shows salient U.S. apparent supply and recycling statistics for selected metals. The value of the 78 million metric tons of domestically recycled metals reported for 1996 in table 1 was about $18 billion.

The U.S. Geological Survey (USGS) provides information and analysis on more than 100 raw and/or processed minerals. Collected data are assessed by commodity specialists, and information is disseminated to government, industry, academia, and the general public through more than 100 periodical publications.

This Mineral Industry Surveys Annual Review summarizes metal recycling. Separate annual reviews are published for each of the metals summarized in this report. Those separate reviews contain more detailed information about both the commodity and recycling of the commodity.

As noted above, the primary source of minerals and metals is mining. The secondary source of metals and other materials is recycled materials. Recycling practices, and the description of those practices, differ substantially among the metal industries covered in this chapter. Generally, scrap is categorized as new or old, where new indicates preconsumer sources and old suggests postconsumer sources. The many stages of industrial processing that precede an end product are the sources of new scrap. For example, when metal is converted into shapes—plates, sheets, bars, rods, etc.—new scrap is generated in the form of cutting, trimmings, and off-specification materials. When these shapes are converted to parts, new scrap is generated in the form of turnings, stampings, cuttings, and off-specification parts. Similarly, when parts are assembled into products, new scrap is generated. Once a product completes its useful life, it becomes old scrap. Used beverage cans are an example of old consumer scrap; used jet engine blades and vanes are examples of old industrial scrap. A wide variety of descriptive terms including home scrap, mill scrap, purchased scrap, prompt scrap, etc. have evolved in response to the wide variety of industry practices.

Aluminum[2]

Aluminum scrap, in one form or the other, is recovered by almost every segment of the domestic aluminum industry. Integrated primary aluminum companies, and independent secondary smelters, fabricators, foundries, and chemical producers recover aluminum from scrap. Integrated primary aluminum companies and independent secondary smelters, however, are the major consumers of scrap.

The independent secondary aluminum smelters consume scrap and produce alloys for the diecasting industry. In the United States, there is a heavy concentration of smelters in the automotive and appliance manufacturing areas of the country.

The other major consumers of aluminum scrap are the integrated aluminum companies. The integrated companies frequently purchase scrap from their industrial customers directly or on a contract conversion basis. Major integrated aluminum companies also operate beverage can recycling programs and have set up literally thousands of collection centers around the country for used aluminum beverage cans.

Used (aluminum) beverage can (UBC) scrap is the major component of processed old scrap, accounting for approximately one-half of the old aluminum scrap consumed in the United States. Most UBC scrap is recovered as aluminum sheet and manufactured back into aluminum beverage cans. Most of the other types of old scrap are recovered in the form of alloys used by the diecasting industry; the bulk of these diecasts are used by the automotive industry.

Metal recovered from scrap has become an important component of aluminum supply in the United States. The aluminum recycling industry has grown dramatically over the last 25 years, increasing from a total metal recovery of 900,000 metric tons in 1970 to almost 3.3 million tons in 1996, according to data derived by the USGS from its "Aluminum Scrap" survey.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries Inc., 62.8 billion aluminum beverage cans were recycled in the United States during 1996. The recycling rate, based on the number of cans shipped during the year, was 63.5%, a slight increase from the 62.2% recycling rate reported

[1]Prepared by John F. Papp.

[2]Prepared by Patricia A. Plunkert.

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in 1995. According to the organizations' joint press release, aluminum beverage cans produced domestically in 1996 had an average 51.6% postconsumer recycled content, the highest recycled content percentage of all packaging materials (Aluminum Association, 1997).

Purchase prices for aluminum scrap, as quoted by American Metal Market (AMM), followed the trend of primary ingot prices and closed the year at slightly lower levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 52 to 52.5 cents per pound; old sheet and cast, 47 to 49 cents per pound; and clean, dry aluminum turnings, 48 to 48.5 cents per pound.

Aluminum producers' buying price range for processed and delivered UBC's, as quoted by AMM, fluctuated during the year from a high of 58 to 60 cents per pound at the beginning of the year and during the months of April and May to a low of 47 to 48 cents per pound during June and July. At yearend, the price ranged from 53 to 54 cents per pound. Resource Recycling published a monthly transaction price for aluminum UBC's in its Container Recycling Report. The average annual UBC transaction price for 1996 was 54.7 cents per pound, a substantial decrease from the 1995 annual average of 66.7 cents per pound.

The yearend indicator prices, as published by AMM, for selected secondary aluminum ingots also decreased compared with those of 1995 and were as follows: alloy 380 (1% zinc content), 79.37 cents per pound; alloy 360 (0.6% copper content), 84.44 cents per pound; alloy 413 (0.6% copper content), 84.66 cents per pound; and alloy 319, 81.50 cents per pound. Platt's Metals Week published an annual average U.S. price of 67.3 cents per pound for A-380 alloy (3% zinc content). The average annual London Metal Exchange cash price for a similar 380 alloy was 59 cents per pound.

Beryllium[3]

Beryllium is used in a wide number of applications where light weight and stiffness properties are important. The United States is one of only three countries that can process beryllium ore and concentrates into beryllium products, and it supplies most of the rest of the world with these products. Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications and average about 75% of annual U.S. consumption on a beryllium metal equivalent basis. Beryllium metal averages about 10% of annual U.S. beryllium demand and is used principally in aerospace and defense applications. Beryllium oxide averages about 15% of U.S. beryllium demand and serves as a substrate for high-density electronic circuits. Because of its high cost compared to those of other materials, beryllium is used in applications in which its properties are crucial. Substitutes such as graphite composites, phosphor bronze, steel, and titanium exist for certain beryllium applications, but with a substantial loss in performance.

In 1996, U.S. apparent consumption of beryllium totaled about 204 tons. Unknown quantities of new scrap generated in the processing of beryllium metal and beryllium-copper alloys were recycled. The new scrap generated during the machining and fabrication of beryllium metal and alloys is returned to the metal-alloy producers for recycling. The beryllium in beryllium-copper fabricated parts is so widely dispersed in products, and so highly diluted when those products are recycled, that it is essentially dissipated. Additionally, smaller quantities of obsolete military equipment containing beryllium were recycled.

Cadmium[4]

Cadmium recycling has been practical only for nickel-cadmium batteries, some alloys, and dust generated during steelmaking in electric arc furnaces (old scrap) and waste from manufacturing processes (new scrap). In other applications cadmium is used at low concentrations and is almost impossible to recycle; consequently, much of this cadmium is dissipated into the environment.

Cadmium from spent industrial nickel-cadmium batteries and cadmium alloys is recovered by a limited number of companies using pyrometallurgical or hydrometallurgical methods. The annual rate of secondary production in the United States amounts to about 500 tons. The largest recycling company, located in Pennsylvania, is using a pyrometallurgical method. There, the larger batteries, usually weighing more than 2 kilograms and containing an average of 15% cadmium, are emptied of their electrolyte, and dismantled mechanically; the remaining cadmium and nickel plates are separated. Detached cadmium plates then go directly into an electric distillation furnace. The plastic castings and separators of the smaller sealed batteries are burned off at a lower temperature before being fed into the furnace. The resulting 99.95% pure cadmium is shipped to battery manufacturers for reuse.

Future collection and recycling of batteries may be spurred by signing into law of The Mercury-Containing and Rechargeable Battery Act of 1996 (Public Law 104-142). The act establishes uniform labeling requirements by May 1998 and provides for streamlining of regulatory requirements governing battery collection and recycling. It is estimated that by the year 2005 roughly 70% of spent nickel-cadmium batteries in the United States will be recycled.

Chromium[5]

The major end use of chromium is in stainless steel and it is in this form that chromium is recycled. Chromite ore is smelted to make ferrochromium, a chromium-iron alloy that results from the removal of oxygen from chromite. Ferrochromium is then added to iron at steel producing plants to make the chromium-containing alloy commonly called stainless steel. Stainless steel

[3]Prepared by Larry Cunningham.

[4]Prepared by Peter H. Kuck.

[5]Prepared by John F. Papp.

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scrap can substitute for ferrochromium as a source for chromium units. Stainless steel comprises two broad categories of grades called austenitic and ferritic. The names are related to the molecular structure of the steel but also identify which grades are nickel-containing (i.e., austenitic) and which are not (ferritic). Nickel content increases the price of the alloy and its scrap.

Scrap is generated during the manufacturing process (new scrap) and as a result of recycling obsolete manufactured products (old scrap). Scrap from these sources is collected and sorted by grade (i.e., chemical composition) in scrap yards. Scrap brokers play a role in moving material from where it is recovered to where it is consumed. The steel industry consumes stainless steel scrap as a source of chromium and nickel units. A study of the domestically produced stainless steel found that its average chromium content is about 17% (Papp, 1991).

Cobalt[6]

Cobalt-bearing scrap originates during manufacture and/or following use in these applications: alloys such as superalloys, magnetic alloys, wear-resistant alloys, and tool steels; cemented carbides used in cutting and wear-resistant applications; catalysts used by the petroleum and chemical industries; and rechargeable batteries. Depending on the type and quality of the scrap, it might be recycled within the industry sector that generated it; processed to reclaim the cobalt as a cobalt chemical or metal powder; downgraded by using it as a source of nickel or iron in an alloy with a lower cobalt content; or processed to an intermediate form that would then either be further refined or downgraded. The products of recycled cobalt scrap include pure cobalt metal, metal powder, chemicals, tungsten carbide-cobalt powders, mixed metal residues, and alloys.

In 1996, scrap consumption reported by U.S. cobalt processors and consumers increased 8% to 1,670 tons of contained cobalt. U.S. imports of cobalt waste and scrap decreased 36% to 566 tons of contained cobalt, valued at $11.7million. Eight countries supplied 93% of these materials: the United Kingdom (21%), Japan (13%), Germany (12%), South Africa (11%), Canada and Finland (each 10%), Brazil (9%), and Russia (7%). U.S. exports of cobalt waste and scrap are reported in combination with exports of unwrought cobalt metal and metal powders.

Copper and Copper Alloy Scrap[7]

Estimated world production of secondary refined copper in 1996 of 2 million tons, a decline of about 100,000 tons from the record-high level in 1995, accounted for about 16% of total world production of refined copper. According to data compiled by the World Bureau of Metal Statistics, an additional 3 million tons of copper were recovered from the direct remelting of copper scrap (World Metal Statistics, 1997). Secondary refined production in the United States declined for the third consecutive year. The decline in 1994-95 was attributed to closure of a major secondary refinery in 1994. In 1996, lower copper prices further discouraged scrap copper recovery.

In 1996, copper recovered from all old and new refined or remelted scrap comprised 35% of total U.S. copper supply and had an equivalent refined value of $3.1 billion. Conversion of old scrap to alloys and refined copper declined for the fourth consecutive year, falling by 15,000 tons, but contributed 428,000 tons of copper to the market, a quantity equivalent to about 15% of U.S. apparent consumption.

Purchased new scrap, derived from fabricating operations, yielded 872,000 tons of copper, an amount essentially unchanged from that of 1995, and accounted for 67% of copper recovered from all scrap. Consumption of new scrap had trended upward over the preceding 4 years, in both absolute terms and as a percentage of total scrap recovery, increasing by almost 200,000 tons, or 28%, since 1991. This large increase in new scrap consumption reflects the increased domestic consumption of mill products. About 79% of the copper contained in new scrap was consumed at brass mills and wire rod mills.

During the year, 7 primary and 4 secondary smelters, 8 electrolytic and 6 fire refineries, and 14 electrowinning plants operated in the United States. Two of the electrolytic refineries were dedicated facilities associated with secondary smelters and mostly processed anode derived from scrap; several other refineries that mainly processed primary anode purchased or tolled some secondary anode. All of the fire refineries processed copper scrap.

Copper was consumed, both as refined copper and as direct melt scrap, at about 35 brass mills, 15 wire rod mills, and 600 foundries, chemical plants, and miscellaneous manufacturers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-based scrap, copper smelters and refiners recovered 26%; brass mills, 55%; brass and bronze ingot makers, 10%; and miscellaneous manufacturers, foundries, and chemical plants, 9%. Unalloyed scrap accounted for 49% of copper-based scrap consumed.

Copper scrap prices trended downward in 1996, following the decline in refined copper prices. However, while the average producer price for refined copper declined by about 29 cents per pound from that of 1995, the refiners buying price for No. 2 scrap declined by only about 20 cents per pound. Thus, the average margin between refined copper and No. 2 scrap declined from 34 cents per pound in 1995 to 25 cents per pound in 1996. In September, the discount averaged only 21 cents per pound. Historically, because of the inherent costs associated with the initial collection and processing of scrap, low refined copper prices squeeze processing and profit margins and reduce the quantity of scrap that can be recovered economically.

The United States was one of the largest international sources for copper scrap, followed by France, Germany, and the United Kingdom. Canada retained its position as the largest recipient of U.S. scrap exports, accounting for 37% of the total.

[6]Prepared by Kim B. Shedd.
[7]Prepared by Daniel L. Edelstein.

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Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap and accounted for 78% of imports in 1996.

Gallium[8]

Virtually all of the gallium used domestically goes into optoelectronic devices and integrated circuits, about 95% of it in the form of gallium arsenide.

Because of the low yield in processing gallium to optoelectronic devices or integrated circuits, substantial quantities of new scrap are generated during the various processing stages. These wastes have varying gallium and impurity contents, depending upon the processing step from which they result. Gallium arsenide (GaAs)-based scrap, rather than metallic gallium, represents the bulk of the scrap that is recycled. During the processing of gallium metal to a GaAs device, waste is generated in several stages. If the ingot formed does not exhibit single crystal structure or if it contains excessive quantities of impurities, the ingot is considered to be scrap. Also, there is some GaAs that remains in the reactor after the ingot is produced, and this may be recycled. During the epitaxial growth process, various wastes are produced, depending on the growth method used. During the wafer preparation and polishing stages, significant quantities of wastes are generated. Before wafers are sliced from the ingot, both ends of the ingot are cut off and discarded, because impurities are concentrated at the tail end of the ingot, and crystal imperfections occur at the seed end. These ends represent up to 25% of the weight of the ingot. As the crystal is sliced into wafers, two types of wastes are generated—saw kerf, which is essentially GaAs sawdust, and broken wafers. When the wafers are polished with an abrasive lapping compound, a low-grade waste is generated. Because GaAs is a brittle material, wafers may break during the fabrication of electrical circuitry on their surfaces. These broken wafers also may be recycled.

The gallium content of these waste materials may vary from less than 1% to as much as 99.99%. Liquid-phase epitaxy wastes normally have the highest gallium content, varying between 98% and 99.99%. Ingot ends and wafers broken during processing generally contain from 39% to 48% gallium, vapor-phase epitaxy exhaust gases contain from 6% to 15% gallium, saw kerf contains up to 30% gallium (wet basis), and lapping compound wastes contain less than 1% gallium. These wastes are contaminated with small quantities of many metallic impurities. In addition to metallic impurities, the scrap may be contaminated with other materials introduced during processing such as water, silicone oils, waxes, plastics, and glass.

In processing GaAs scrap, the material is crushed, if necessary, then dissolved in a hot acidic solution. This acidic solution is neutralized with a caustic solution to precipitate the gallium as gallium hydroxide, which is filtered from the solution and washed. The gallium hydroxide filter cake is redissolved in a caustic solution and electrolyzed to recover 99.9% to 99.99% gallium metal.

Some GaAs manufacturers may recycle their own scrap, or scrap may be sold to metal traders, to a company that specializes in recycling GaAs, or to the GaAs manufacturer's gallium supplier, who can recover the gallium and return it to the customer. Generally the prices commanded by GaAs scrap parallel the price fluctuations of 99.99% gallium metal. Also, prices are dependent on the type and gallium content of the scrap.

GaAs scrap that is recycled is new scrap, which means that it has not reached the consumer as an end product, and it is present only in the closed-loop operations between the companies that recover gallium from GaAs scrap and the wafer and device manufacturers. Because this closed loop occasionally crosses international boundaries, it is difficult to distinguish between gallium recovered from scrap and virgin gallium when evaluating the gallium supply of an individual country.

Gold[9]

Old scrap is gold-containing products that have been discarded after use, and generally contributes 5% to 10% of the total U.S. supply of gold. New scrap is gold scrap generated during the manufacturing process, and for the most part remains the property of the manufacturers, so it is not counted as part of the market supply. The scrap component of the gold supply is perhaps the most difficult of all metal supply components to quantify. In many areas of the world, especially in those areas where the holding of gold is encouraged by tradition, secondary gold, especially that derived from relatively crude gold jewelry, changes hands both locally and internationally from purchasers to goldsmiths and back again to purchasers. This flow is often in response to variations in the gold price and usually cannot be followed statistically.

A considerable quantity of scrap is generated in manufacturing operations, but because of tight controls over waste materials in precious metals plants, nearly all of this "home-generated" scrap can be recovered. Probably the greatest loss in gold fabrication occurs in gold plating plants where fouled or depleted solutions are sometimes discarded. Some old scrap, on the other hand, is lost because in practice gold cannot be economically recovered from all manufactured products.

Gold-bearing scrap is paid for on the basis of gold content, determined by analytical test, and the market price for gold on the day that the refined product is available for sale. Processing charges and adjustments for processing losses are deducted from the total value in settling payments. Aside from dealer-processors and refiners there are no markets for recycled gold. The Federal Trade Commission requirement for karat identification of jewelry alloys effectively forces gold refiners to know the chemical analysis of the alloys they purchase and gold refiners to separate the constituents of scrap to assure meeting karat standards.

[8]Prepared by Deborah A. Kramer.

[9]Prepared by Earle B. Amey.

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Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from the current manufacturing operations, and the remainder comes from old scrap in the form of items such as discarded jewelry and dental materials, used plating solutions, junked electronic equipment which includes computers, etc. Most of the domestic scrap is processed by approximately two dozen refiners located in the Northeastern States, although the current trend seems to be toward a less centralized industry. The number of domestic fabricators approaches 3,000. Scrap dealers may process the scrap and then ship the upgraded product to refiners and fabricators for further treatment and refining. The U.S. Department of Defense (DOD) recovers significant quantities of gold from military scrap. Other federal government agencies either participate in the DOD recovery program or have one of their own.

Data for domestic consumption of new and old scrap, collected by the USGS, are currently under review for future publication. The United States has for many years been a net exporter of gold scrap. In 1996, the United States continued for the fifth straight year to increase its exports while decreasing its role as a scrap importer.

Prices for gold waste and scrap imported and exported in 1996 averaged $244 and $295 per troy ounce, respectively; at the same time, the average price for gold was $389 per ounce.

Indium[10]

Recycling of indium became significant for the first time in 1996 and was said by industry sources to have affected the market and prices. The increase in recycling was a result of the rapid increase in indium prices in 1995. The addition of secondary metal to the supply brought the domestic indium price down in 1996, from $16.25 per troy ounce at the beginning of the year to $6.53 per ounce at yearend. Nearly one-half of the indium consumed domestically goes into indium-tin-oxide thin-film coatings used for liquid crystal displays in such products as flat television screens. A sputtering process is used in manufacturing the thin-films; most of the augmented secondary indium production was derived from used sputtering targets and scrap from their manufacture. Old scrap was available for recycling only in very small quantities. An estimate of the amount of refined indium produced through recycling is not available.

Iron and Steel Scrap[11]

Iron, including its refined product steel, is the most widely used of all the metals, and the recycling of iron and steel scrap (ferrous scrap) is an important activity worldwide. Iron and steel products are used in many construction and industrial applications, such as in vehicles, buildings, bridges, highways, machinery, tools, appliances, and containers. Because it is economically advantageous to recycle iron and steel by melting and recasting into semifinished forms for use in the manufacture of new steel products, a significant industry has developed to collect used and obsolete iron and steel products and ferrous scrap generated in steel mills and steel-product manufacturing plants.

A vast quantity of ferrous scrap available for recycling is comprised of home, prompt, and obsolete scrap. Home or mill scrap is generated within the steel mill during production of iron and steel. Trimmings of products and defective products are collected and quickly recycled back into the steel furnace because their chemical compositions are known. The availability of home scrap has been declining as new and more efficient methods of casting have been adopted by the industry. Prompt or industrial scrap from manufacturing plants that make steel products is the most important source of recycled iron. Because its chemical and physical characteristics are known, it is usually transported quickly back to steel plants for remelting to avoid storage space and inventory control costs. Obsolete, old, or post-consumer scrap is also available for recycling. The largest source of obsolete scrap is junked automobiles, followed by demolished steel structures, wornout railroad cars and tracks, appliances, and machinery. Obsolete scrap requires more processing for steel mill buyers by scrap collectors, such as sorting, de-tinning, and de-zincing, because of the wide variety of chemical and physical characteristics.

About 5,000 establishments, ranging in size from large corporations to small family dealers, play an integral role in the steel industry by collecting and preparing scrap for transport to steel mills needing raw materials. Scrap dealers process scrap, using a variety of equipment, into a physical form and chemical composition that steel mill furnaces can consume. Dealers specializing in the processing steel cans receive loads of these from smaller dealers or have partnership arrangements with neighborhood waste removers. Cans are crushed, using balers, into heavy cubes called bales that weigh as much as a ton. Recycled automobiles accounted for about one-sixth of the ferrous scrap recycled by the United States' steel industry in 1996. More than 200 scrapyards crushed automobiles and shredded them into fist-sized pieces, which were then passed over by powerful magnets to segregate steel from plastics, aluminum, and other materials. Appliances, bicycles, and other steel products are also shredded for recycling. More than 1,500 scrapyards process steel from construction and demolition sites by shearing, shredding, and baling.

Manufactured steel products have a wide range of physical and chemical characteristics according to relative contents of the alloying elements carbon, chromium, cobalt, manganese, molybdenum, nickel, silicon, tungsten, and vanadium. Also, some steel products are coated with aluminum, chromium, copper, lead-tin alloy, nickel, tin, or zinc. For these reasons, scrap dealers must carefully sort the scrap they sell and steelmakers must be careful to purchase scrap that does not contain undesirable elements, or residuals, that exceed acceptable levels, which differ according to the product being produced.

Steel mills melt scrap in basic-oxygen furnaces (BOF) and

[10]Prepared by Robert D. Brown, Jr.
[11]Prepared by Michael Fenton.

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electric arc furnaces (EAF) and, to a minor extent, in blast furnaces. The proportion of scrap in the charge in a BOF is limited to less than 30%, whereas the charge in the EAF can be as much as 100% scrap. Steel and iron foundries use scrap in EAF's and cupola furnaces. In 1996, BOF's were used to produce 57% of total steel in the United States, while using only 22% of total scrap consumed. During the same period, EAF's produced 43% of total steel, while using 64% of total scrap consumed.

Iron and steel scrap is an additional resource for steelmakers that is more than just economically beneficial. Recycling conserves natural resources, energy, and landfill space. Recovery of 1 ton of steel from scrap conserves an estimated 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone. One pound of recycled steel saves enough energy to light a 60-watt bulb for more than 26 hours.

Ferrous scrap is traded worldwide. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars, consumer durables, and manufacturing operations, the mature industrialized economies are the main exporters of scrap. The main trade flows of scrap are from heavily industrialized and developed countries of North America and northern Europe to the lesser developed countries of southern Europe and the Pacific rim. The United States continued to be the leading exporting country of iron and steel scrap in 1996. Other major exporters of ferrous scrap were France, Germany, the Netherlands, and the United Kingdom. The most significant importing nations were, in decreasing order of magnitude, Turkey, Italy, the Republic of Korea, Spain, Belgium-Luxembourg, and the Netherlands. Other Asian importers were China, India, and Japan, which individually imported only about one-fourth of that imported by the Republic of Korea.

The U.S. trade surplus for all classes of ferrous scrap was 5.6 million tons in 1996 (Bureau of the Census, unpub. data, 1996). Total U.S. exports of carbon steel and cast-iron scrap went to 61 countries in 1996 and totaled 7.46 million tons. The largest tonnages, in declining order of size, went to the Republic of Korea, Canada, Mexico, Turkey, Malaysia, and India. Total U.S. exports of stainless steel scrap went to 42 countries and consisted of 303,000 tons. The largest tonnages, in declining order of size, went to the Republic of Korea, Spain, Canada, Taiwan, and Japan. U.S. exports of alloy steel scrap (excluding stainless steel) in 1996 were shipped to 43 countries and consisted of 674,000 tons. The largest tonnages went to Canada and Mexico.

Lead[12]

About 75% of the refined and alloyed lead produced in the United States in 1996 was recovered from recycled scrap, of which the major source was spent lead-acid storage batteries. The recycled batteries consisted of the starting-lighting-ignition type used in automotive applications, as well as the industrial-type used in applications such as uninterruptible power-supply equipment, load-leveling equipment for commercial electrical power systems, industrial forklifts, airline ground equipment, and mining vehicles. Less than 10% of the recycled lead was recovered from other lead-based sources including solder, cable covering, building construction materials, and drosses and residues (new scrap) from primary smelter-refinery operations.

Recycled lead currently is produced by 25 companies operating 31 secondary lead smelter-refinery plants. More than 95% of the recycled lead is produced by 18 companies. Most of the recycled lead is recovered either as soft lead or lead alloys to be reused in the manufacture of lead-acid storage batteries. Storage batteries accounted for nearly 88% of the reported consumption of lead in the United States in 1996.

During the period 1992-96, the United States exported an average of about 80,000 tons per year of lead-bearing scrap including battery as well as nonbattery forms. Only minimal quantities of lead-bearing scrap were imported during this period. The spot price for smelter's scrap lead averaged about 16 cents per pound during this period. The average North American Producer price for refined lead was about 39 cents per pound.

The completed expansion of one secondary lead smelter in 1996 effectively increased production capacity by 11,000 tons. Two new smelters were in either the construction or planning stage during the year, and upon completion were expected to add another 64,000 tons of smelter capacity by the end of 1998.

Magnesium[13]

Recycled magnesium is derived from two sources—aluminum- and magnesium-base scrap. Aluminum-base scrap consists of new and old scrap of aluminum-magnesium alloys. The primary component of aluminum-base scrap, from which magnesium is recovered, is used aluminum beverage cans. Although only about 75% of the magnesium originally present in these types of alloys is recovered, it represents a substantial source of secondary magnesium. Magnesium in these aluminum alloys is not separated from the aluminum; rather it remains as an alloying constituent when the beverage can scrap is recycled.

Magnesium-base scrap generally is in forms similar to those of other nonferrous metals. Castings, gates, runners, drippings, turnings, and drosses from processing operations are the principal sources of new scrap. Old scrap comes from a variety of sources, including aircraft parts, military applications, and discarded power tools.

Melting is the most common process used to recycle magnesium, because it allows almost all types of scrap to be processed into various secondary end products. Magnesium scrap normally is received loose on trailers. Because magnesium resembles aluminum closely, there is usually a certain percentage of aluminum scrap mixed in the with magnesium scrap. The aluminum scrap is hand-sorted from the

[12]Prepared by Gerald R. Smith.

[13]Prepared by Deborah A. Kramer.

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magnesium scrap, and the magnesium scrap then is sorted by alloy. Sorting is a critical step in producing a product of desired specifications.

In melting, sorted scrap is charged to a steel crucible and heated to 675° C. As the scrap at the bottom begins to melt, more scrap is added. The liquid magnesium at the bottom is covered with a flux or inhibitive gas to control surface burning. After any alloying elements are added, such as aluminum, manganese, or zinc, and melting is complete, molten magnesium is transferred to ingot molds by either hand ladling, pumping, or tilt pouring.

In addition to melting, magnesium scrap may be recycled by direct grinding of the scrap into powder for iron and steel desulfurization applications. This method is limited to using only specific types of clean scrap. Drosses and other contaminated scrap are not used because they can introduce impurities into the finished product, and these types of scrap can increase the danger of fire in the direct grinding.

Trade in magnesium scrap represents a small portion of the overall U.S. supply of magnesium-base scrap. In general, imports and exports of magnesium waste and scrap have been equivalent over the last 5 years.

As more magnesium is used in automotive applications, North American firms plan to construct new magnesium recycling plants. These plants are expected to process primarily new scrap resulting from automotive component diecasting operations, although many of them also will be able to process less pure grades of scrap.

Manganese[14]

Scrap recovery specifically for manganese is insignificant. Manganese is recycled incidentally as a minor component within scrap of another metal, particularly steel and, to a much lesser degree, aluminum. High-manganese (Hadfield) steel, which has a manganese content of about 12%, is recovered for its manganese content, but the quantity of such scrap is believed to be well below 1% of the total quantity of purchased steel scrap. Recycling of steel and aluminum are discussed in the respective sections of this report. Manganese is ubiquitous throughout the various grades of steel, which on average contain about 0.7% manganese. Although the quantity of manganese units being returned to steelmaking corresponds to about two-thirds of a current U.S. apparent consumption of manganese of about 700,000 metric tons, the manganese in recycled steel scrap can be thought of as providing only a baseline level of manganese. Contents above this are removed in the decarburization step of steelmaking, and then have to be added back. Manganese is recycled in the aluminum industry as a component of scrap of certain manganese-bearing aluminum alloys, principally used beverage cans, in which the manganese content is about 1%. Melting and processing of aluminum is nonoxidizing toward manganese, so that most of the manganese is retained. Currently, the amount of manganese being recycled in the aluminum industry is estimated to be in the vicinity of 1% of manganese apparent consumption. In the future, small additional amounts of manganese could be recovered through widespread recycling of dry cell batteries.

[14]Prepared by Thomas S. Jones.

Mercury[15]

The current trend in the United States is to avoid the discharge or disposal of mercury-containing products. As a result, secondary mercury is recovered from a wide-range of source material. Electronic devices including rectifiers, switches, thermostats, and relays; dental amalgams; batteries; and other instruments such as thermometers are all processed to recover any contained mercury. However, the largest source of secondary mercury remains the spent catalysts used in the production of chlorine and caustic soda. Three companies, one each in Illinois, New York, and Pennsylvania, produce the bulk of secondary mercury in the United States. Mercury waste generated in the manufacturing of products (new scrap) is either reused internally, or collected for reprocessing. Over the period 1992-96, in the United States, the recovery of secondary mercury has increased as industrial consumption has declined. Thus, in both 1995 and 1996, more mercury was recovered than was consumed. In 1996, 446 tons was recovered and 372 tons was consumed.

Molybdenum[16]

Secondary molybdenum in the form of metal or superalloys was recovered, but the amount is small. About 1,000 tons of molybdenum was reclaimed from spent catalysts. Although some molybdenum was recycled as a minor constituent of scrap alloy steels and iron, the use of such scrap did not generally depend on its molybdenum content.

Nickel[17]

U.S. industry recycles a broad spectrum of nickel-bearing materials. The largest source of secondary nickel is stainless steel scrap, which accounted for about 80% of the 59,200 tons of nickel reclaimed in 1996. The 80% represents not only scrap used in raw steel production, but also lesser amounts of scrap consumed by steel and iron foundries, as well as nickel reclaimed from stainless steelmaking residues (e.g., furnace dust, grindings, and mill scale). An additional small percentage came from the recycling of alloy steel scrap. Both old and new scrap are used by stainless steel producers, who are more concerned about the grade of the scrap and levels of critical impurities than about its origin. The five leading producers of austenitic stainless steel in the United States all have their principal melt shops in Pennsylvania. An additional 10 companies have medium to small melt shops scattered

[15]Prepared by Robert G. Reese, Jr.
[16]Prepared by John W. Blossom.
[17]Prepared by Peter H. Kuck.

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throughout the eastern United States that make austenitic stainless products largely for niche markets. A facility at Ellwood City, PA, converts a variety of nickel and chromium wastes into a remelt alloy suitable for stainless steelmaking.

Copper-nickel alloy scrap and aluminum scrap accounted for about 10% of the nickel reclaimed in 1996. Scrap in this category comes from a myriad of sources and includes cupronickel (a series of copper alloys containing 2% to 45% nickel), the Monels (a group of alloys typically containing 65% nickel and 32% copper), nickel-silver (a misnomer for a series of copper-zinc-nickel alloys), and nickel-aluminum bronze. Cupronickel is stronger and more resistant to oxidation at high temperatures than pure copper, making it desirable for saltwater piping and heat exchanger tubes. Nickel-silver—a white brass—is used for rivets, screws, camera parts, and optical equipment. The remaining 10% of reclaimed nickel came from pure nickel scrap and nickel-base alloy scrap. Superalloy producers and downstream fabricators of turbine engines and chemical processing equipment generate a large part of this material—some of which is sent to scrap processors for salvaging and cleaning and later returned to the superalloy producers for remelting. However, because of the stringent specifications for superalloys, much of the superalloy and other nickel-base scrap is not suitable for direct recycling and is sold to stainless steel producers, steel foundries, or specialty alloy casting companies. Aircraft engine repair facilities are an important source of obsolete superalloy scrap. The U.S. collection and recycling program for nickel-cadmium and nickel-metal hydride batteries is in a period of rapid expansion. Federal legislation passed in 1996 has helped spur the program. The program is administered by the Rechargeable Battery Recycling Corporation, a nonprofit public service corporation funded by manufacturers, importers, and distributors of batteries and battery-operated products.

Platinum-Group Metals[18]

In the United States, there was an increase in the average platinum-group metals (PGM) loading of spent automobile catalysts collected in 1996, as the proportion of recent models, which carry a higher PGM content, increased. As a result, PGM recoveries increased to about 14.6 tons in 1996. Historically, about 70% of new cars registered in the United States eventually become available as scrap. If certain assumptions are made about the types of catalysts used in the converters and the amounts of PGM contained, it can be assumed that the scrapped converters contained about 16.2 tons of palladium, platinum, and rhodium. Most cars dismantled in 1996 were equipped with three-way catalytic converters. Although only small quantities of PGM were recovered from catalysts used by the chemical process industry, substantial quantities of platinum were recovered, on a toll basis, from spent petroleum refining catalysts, and then reused in catalysts.

[18]Prepared by Henry E. Hilliard.

Selenium[19]

Most selenium, except for that used in photocopiers, is dissipated or reaches a final disposition as a minor constituent of products that are landfilled. The small quantities added to clear glass as a decolorant or to ferrous and nonferrous metal alloys are not accounted for during the recycling of these materials, and are probably volatilized during remelting. Selenium rectifiers, once a major source of old scrap, generally have been replaced by silicon rectifiers; high processing costs have made it uneconomical to recover the metal from scrapped rectifiers.

While there is currently no domestic secondary selenium recovery, manufacturing scrap generated in the production of selenium-coated photoreceptor drums for plain paper copiers (new scrap) and worn out or obsolete photoreceptor drums (old scrap) are exported for recovery of the contained selenium. It is estimated that as much as about 100 metric tons, or one-fourth of the selenium metal imported annually, is refined from scrap. Practically all of the selenium used in photoreceptor drums is recovered through very efficient recycling programs. Secondary selenium is recovered by Canadian, European, Japanese, and Philippine refiners. The photocopier market for selenium, currently the main feed source for secondary selenium, is expected to continue its decline owing to competition from other technologies, mainly organic photoreceptors. This, combined with low prices and surplus foreign secondary capacity, discourages the redevelopment of domestic secondary production capacity.

Silver[20]

Photographic scrap is estimated to have generated about 1,000 tons of silver in 1996. The major part of this was recycled from spent fixer solutions but a significant quantity also came from solid waste including X-ray and graphic arts film, "wool" from solution tanks, and a small quantity directly from color film negatives.

Nearly all silver that goes into catalysts is recycled, with typical losses being 2% or less. Usually catalysts are scrapped on a 1- to 3-year basis. The worldwide recycling of spent silver catalysts is dominated by a few specialized companies in Europe and the United States. Total supply of silver from the recycling of old silver scrap in the United States in 1996 is estimated at about 1,300 tons.

Tantalum[21]

Tantalum is a refractory metal that is ductile, easily fabricated, has a high melting point, is highly resistant to corrosion by acids, and is a good conductor of heat and electricity. Tantalum is also critical to the United States because

[19]Prepared by Robert D. Brown, Jr.
[20]Prepared by Henry E. Hilliard.
[21]Prepared by Larry Cunningham.

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of its defense-related applications in aircraft, missiles, and radio communications. Currently the major use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. Alloyed with other metals, tantalum is also used in making carbide tools for metalworking equipment and in the production of superalloys for jet engine components. Substitutes such as aluminum, ceramics, columbium (niobium), platinum, titanium, and tungsten exist for tantalum but are usually made at either a performance or economic penalty. There has been no significant mining of tantalum in the United States since the 1950's. Most domestic resources of tantalum are of a low grade and not currently commercially recoverable. Consequently, the United States is highly import dependent for its tantalum raw material supply. Australia is the major source for U.S. tantalum imports.

Recycling of tantalum largely takes place within the processing and product producing industry and is mostly new scrap that is consumed internally. In addition, quantities of tantalum are recycled indirectly in the form of used tantalum-bearing cutting tools and high-temperature alloy melting scrap. In recent years, the recycling of tantalum in tantalum capacitors from carefully collected and sorted electronic components, has acquired considerable significance. Tantalum recovery from tantalum capacitor scrap requires special techniques owing to the different types of scrap. Tantalum can be recovered from certain capacitor scrap by electrolysis and acid leaching. In 1996, U.S. apparent consumption of tantalum totaled about 490 tons, with consumed scrap (from various sources) accounting for an estimated 20% of the total.

Tin[22]

About 25% of the domestic supply of tin metal is recovered from scrap. In 1996, 11,000 metric tons of tin metal valued at an estimated $100 million was recovered from new and old tin scrap. Old tin scrap is collected at hundreds of domestic scrap yards, at seven detinning plants, and at most municipal collection/recycling centers. New tin scrap is generated mainly in the tin mills at six steel plants, scores of canmaking facilities, numerous brass and bronze plants, and many solder-making plants. Most tin scrap processing facilities are close to the tin-using industries and to densely populated areas. Most are in the Midwest and Northeast.

Detinning facilities are unique to the tin scrap industry, in that no other major metal industry has large-scale facilities to remove plated metal. Detinning operations are performed on new tin-plate scrap from tin mills or canmaking plants and on old tin-plate scrap in the form of used (post-consumer) tin cans. The detinning process is the only technique in the secondary tin industry by which free tin metal sees its way to the marketplace. The bulk of the secondary tin industry works with the various alloy forms of tin (brass/bronze, solder, etc.); the tin is recycled within its own product-line industries and thus reappears in regenerated alloys.

The Steel Recycling Institute (SRI) continued to promote the recycling of used tin cans, which over the past 15 years have become an important raw material for the nation's steel industry. SRI announced that the steel can recycling rate had grown from 15% in 1988 to 58% in 1996 (Container Recycling Report, 1997).

Tin scrap prices are rarely published but generally approximate the prices for primary tin metal.

Titanium[23]

About 95% of titanium domestic consumption is in the form of titanium dioxide, which is employed as a pigment in paints, paper, plastics, etc., none of which is directly recycled. Most of the remaining 5% of domestic consumption is in the form of metal primarily used in aerospace applications. The extensive processing of titanium metal generates large quantities of scrap compared to most other metals.

Titanium scrap comprises about one-half of the feedstock for titanium ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of titanium components. In addition, some obsolete or old scrap is recycled from old aircraft components, heat exchangers, etc. Although no data are available as to the percentage breakdown of sources of titanium scrap, it has been estimated that less than 2% of titanium ingot production is derived from old scrap.

Scrap is recycled with or without virgin metal by titanium ingot producers using vacuum-arc-reduction or cold-hearth melting practices. Prior to melting, scrap must be analyzed, classified, and processed to remove impurities. Several companies have proprietary processes to accomplish this task.

Titanium scrap is consumed by the steel industry as scrap or it may first be converted to ferrotitanium. Currently, there are two domestic producers of ferrotitanium. Ferrotitanium consumption by the steel industry is largely associated with the production of stainless steels, where it is used as an alloying ingredient or as a gas scavenger. Titanium scrap is also used to produce aluminum-titanium master alloys for the aluminum industry. Titanium improves casting and reduces cracking in aluminum alloys.

Demand for titanium from commercial aerospace and golf club markets resulted in a 28% annual increase in titanium scrap consumption in 1996. However, imports of scrap increased 48% and producer in-house receipts of titanium scrap increased 22%. Meanwhile, 1996 yearend stocks rose 69% compared with those at yearend 1995. Owing to the increased abundance of titanium scrap in spite of high demand, prices for scrap turnings and ferrotitanium decreased 5% and 2%, respectively.

Tungsten[24]

An estimated 30% of world tungsten supply is from recycled

[22]Prepared by James F. Carlin, Jr.

[23]Prepared by Joseph Gambogi.

[24]Prepared by Kim B. Shedd.

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materials. Tungsten-bearing scrap originates during manufacture and/or after use in the following applications: cemented carbides used for cutting and wear-resistant applications; mill products made from metal powder such as filaments and electrodes for lamps and heavy metal alloys; and alloys such as tool steels, high-speed steels, and superalloys. Depending on the type and quality of the scrap, it can be recycled by the industry sector that generated it, used as a source of tungsten by another consuming industry, or used as a substitute for tungsten concentrate by tungsten processors.

Cemented carbide scrap is recycled by several different processes. Some processes result in tungsten carbide powder combined with cobalt, which can be used to make new cemented carbide parts. In other processes, the cobalt is recovered separately and the tungsten is converted to the intermediate product ammonium paratungstate, from which tungsten chemicals, metal powder, or carbide powder can be produced. Tungsten metal scrap from the manufacture of mill products is used to make superalloys, tool steel, cast carbides, and ferrotungsten. It can also be processed chemically to produce ammonium paratungstate. Most heavy metal alloy manufacturing scrap is recycled as home scrap to a prealloyed powder, but it can also be used to produce tool steel, or be chemically converted to ammonium paratungstate. Steel scrap and superalloy scrap are recycled by the steel and superalloy industries, respectively.

In 1996, scrap consumption reported by U.S. tungsten processors and consumers increased 7% to 2,560 tons of contained tungsten. U.S. imports of tungsten waste and scrap decreased 13% to 1,840 tons of contained tungsten, valued at $11.0 million. Two-thirds of these imports were supplied by four countries (Japan, 19%; the United Kingdom, 17%; Russia, 16%; and Germany, 15%). U.S. exports of tungsten waste and scrap decreased 19% to an estimated 565 tons of contained tungsten, valued at $3.6 million. An estimated 60% of these exports were sent to Germany.

Vanadium[25]

The principal use of vanadium is as an alloying element. Very small quantities of vanadium, often less than 1%, are alloyed with other metals to produce various ferrous and nonferrous alloys. Owing to the relatively small amount of vanadium involved, these alloys in general do not lend themselves to recycling for vanadium recovery. Vanadium is also used as a catalyst. It is estimated that catalyst consumption accounts for less than 1% of the total U.S. vanadium consumption. However, processing spent vanadium catalysts accounts for the only significant source of refined secondary vanadium. Three plants located in Arkansas, Louisiana, and Texas accounted for most of the recycled vanadium catalyst. Any new scrap generated in either the production of alloys or catalysts is likely reused internally.

[25]Prepared by Robert G. Reese, Jr.

Zinc[26]

About 30% of the world's zinc is produced from secondary materials, recovered from brass, galvanizing residues, diecasting scrap, zinc sheet, and flue dust. In the United States, about one-fourth of the 1.45 million tons of zinc consumed annually by domestic industries is secondary zinc. Nearly two-thirds of recycled zinc in 1996 was derived from new scrap, generated mainly in galvanizing and diecasting plants and brass mills. The remaining one-third was obtained from old diecasts, brass products, old rolled zinc articles, and flue dust from EAF. Recycled zinc was used by 11 primary and secondary smelters for production of zinc metal, including alloys, and an additional 12 plants produced zinc chemicals, mainly zinc oxide. The Zinc Corporation of America's plant in Monaca, PA, is by far the largest processor of secondary zinc.

Because of wide differences in the character and content of zinc-bearing scrap, zinc recycling processes vary widely. Clean new scrap, mainly brass, rolled zinc clippings, and rejected diecastings, usually require only remelting. In the case of mixed nonferrous shredded metal scrap, zinc is separated from other materials either by hand, by magnetic separation, or by the floatation method. Most EAF dust is recovered by using the Waelz process. Because the most common use of zinc is for galvanizing, the latest research is aimed mainly at stripping zinc from galvanized steel scrap.

Trade in zinc scrap, measured in gross weight, is relatively small—about 3% of total scrap consumption. Around 85% of imported zinc scrap was supplied by Canada, while the major destination of U.S. exports was Taiwan. Prices for scrap vary according to quality, presence of other components, geographic location, and environmental difficulties in handling, transporting, or treating. The price for a ton of zinc metal contained in scrap is about three-fourths of the London Metal Exchange price for refined zinc metal.

Zirconium[27]

Zirconium scrap comprises about one-half of the feedstock for ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of zirconium components. In addition, some obsolete or old scrap is recycled from dismantled process equipment, vessels, heat exchangers, etc. Although no data are available as to the percentage breakdown of sources of scrap, it is estimated that less than 2% of ingot production is derived from old scrap. Prior to melting, scrap must be analyzed, classified, and processed to remove impurities. Several companies have proprietary processes to accomplish this task. Scrap is initially melted without virgin metal by the two domestic ingot producers, Wah Chang, Albany, OR, and Western Zirconium, Ogden, UT, using vacuum-arc-reduction melting practices.

[26]Prepared by Jozef Plachy.
[27]Prepared by Joseph Gambogi.

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[1]Prior to January 1996, prepared by the U.S. Bureau of Mines.

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TABLE 1
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

Year	Quantity of metal (metric tons)					Value of metal (thousands)			
	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 5/	Percent recycled	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 6/
Aluminum: 7/									
1992	1,140,000	1,610,000	2,760,000	6,870,000	40	$1,450,000	$2,040,000	$3,500,000	$8,710,000
1993	1,310,000	1,630,000	2,940,000	7,920,000	37	1,540,000	1,920,000	3,460,000	9,300,000
1994	1,580,000	1,500,000	3,090,000	8,460,000	36	2,480,000	2,360,000	4,840,000	13,300,000
1995	1,680,000	1,510,000	3,190,000	8,010,000	40	3,190,000	2,850,000	6,040,000	15,200,000
1996	1,710,000	1,570,000	3,290,000	8,340,000	39	2,690,000	2,470,000	5,160,000	13,100,000
Chromium: 8/									
1992	NA	NA	102,000	378,000	27.0	NA	NA	89,400	331,000
1993	NA	NA	92,000	484,000	19.0	NA	NA	62,500	328,000
1994	NA	NA	99,000	390,000	25.4	NA	NA	63,100	249,000
1995	NA	NA	112,000	566,000	19.8	NA	NA	136,000	688,000
1996	NA	NA	98,400	480,000	20.5	NA	NA	95,100	464,000
Copper: 9/									
1992	723,000	555,000	1,280,000	3,030,000	42.2	1,710,000	1,310,000	3,030,000	7,170,000
1993	748,000	543,000	1,290,000	3,260,000	39.6	1,510,000	1,100,000	2,610,000	6,590,000
1994	827,000	500,000	1,330,000	3,510,000	37.9	2,030,000	1,230,000	3,250,000	8,580,000
1995	874,000	443,000 r/	1,320,000	3,410,000 r/	38.6	2,670,000	1,350,000	4,020,000	10,400,000
1996	872,000	428,000	1,300,000	3,700,000	35.1	2,100,000	1,030,000	3,120,000	8,910,000
Iron and steel: 10/									
1992	NA	NA	63,000,000	139,000,000	45	NA	NA	5,960,000	13,200,000
1993	NA	NA	68,000,000	167,000,000	41	NA	NA	6,440,000	18,800,000
1994	NA	NA	70,000,000	178,000,000	39	NA	NA	6,630,000	22,600,000
1995	NA	NA	72,000,000	180,000,000	40	NA	NA	6,820,000	24,300,000
1996	NA	NA	72,000,000	183,000,000	39	NA	NA	6,820,000	23,900,000
Lead: 11/									
1992	55,400	861,000	916,000	1,330,000	69.1	42,900	666,000	709,000	1,030,000
1993	55,000	838,000	893,000	1,380,000	64.7	38,500	587,000	625,000	966,000
1994	54,200	877,000	931,000	1,540,000	60.5	44,400	719,000	763,000	1,260,000
1995	46,400	926,000	972,000	1,580,000	61.5	43,300	863,000	906,000	1,470,000
1996	36,600	1,050,000	1,090,000	1,630,000	66.8	39,400	1,130,000	1,170,000	1,750,000
Magnesium: 12/									
1992	26,200	30,800	57,000	168,000	34	78,000	91,700	170,000	500,000
1993	28,300	30,600	58,900	176,000	34	81,700	88,400	170,000	508,000
1994	32,500	29,600	62,100	182,000	34	103,000	94,000	197,000	578,000
1995	35,400	29,800	65,100	206,000	32	150,000	126,000	276,000	872,000
1996	40,800	30,100	70,900	205,000	35	169,000	125,000	294,000	850,000
Nickel: 13/									
1992	NA	NA	55,900	159,000	35.1	NA	NA	391,000	1,120,000
1993	NA	NA	54,000	158,000	34.1	NA	NA	286,000 r/	839,000
1994	NA	NA	58,600	164,000	35.8 r/	NA	NA	371,000	1,040,000
1995	NA	NA	64,500 r/	181,000 r/	35.6 r/	NA	NA	531,000 r/	1,490,000 r/
1996	NA	NA	59,200	183,000	32.4	NA	NA	444,000	1,370,000
Tin: 14/									
1992	4,890	8,850	13,700	37,300	37	43,400	78,400	122,000	331,000
1993	4,190	6,950	11,100	43,300	26	32,300	53,500	85,800	334,000
1994	4,290	7,380	11,700	41,900	28	34,800	59,900	94,800	340,000
1995	3,880 r/	7,720 r/	11,600 r/	43,300 r/	27	35,800 r/	70,800 r/	107,000 r/	397,000 r/
1996	3,460	7,580	11,000	37,700	29	31,400	68,800	100,000	342,000
Titanium: 15/									
1992	NA	NA	14,800	W	51	NA	NA	23,600 e/	NA
1993	NA	NA	15,300	W	50	NA	NA	14,300 e/	NA
1994	NA	NA	15,700	W	48	NA	NA	26,800 e/	NA
1995	NA	NA	20,500	W	49	NA	NA	41,800 e/	NA
1996	NA	NA	26,300	W	48	NA	NA	50,700 e/	NA
Zinc: 16/									
1992	234,000	132,000	366,000	1,280,000	28.7	301,000	170,000	471,000	1,640,000
1993	246,000	109,000	355,000	1,370,000	26.0	250,000	111,000	361,000	1,400,000
1994	245,000	116,000	361,000	1,400,000	25.9	208,000	126,000	335,000	1,510,000
1995	242,000 r/	111,000 r/	353,000	1,460,000	24.2	298,000 r/	137,000 r/	435,000	1,800,000
1996	265,000	114,000	379,000	1,450,000	26.1	273,000	115,000	388,000	1,640,000

See footnotes at end of table.

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TABLE 1-Continued
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Scrap that results from the manufacturing process, including metal and alloy production. Aluminum, copper, lead, tin, and zinc new scrap excludes home scrap. Home scrap is scrap generated in the metal producing plant.

3/ Scrap that results from consumer products.

4/ Metal recovered from new plus old scrap.

5/ Production plus net imports plus stock changes. Production is primary production plus recycled metal. Net imports are imports minus exports. Apparent supply is calculated on a contained weight basis.

6/ Same as apparent supply defined above but calculated on a monetary value basis.

7/ Scrap quantity is the calculated metallic recovery from reported purchased new and old aluminum-based scrap, estimated for full industry coverage. Monetary value is estimated based on average U.S. market price for primary aluminum metal ingot.

8/ Secondary production measured as chromium contained in reported stainless steel scrap receipts where chromium content was estimated at 17%. Value calculated from quantity using the average annual value of high-carbon ferrochromium as follows in dollars per metric ton of contained chromium: 1992--875; 1993--679; 1994--638; 1995--1,216; 1996--731.

9/ Monetary value based on annual average refined copper prices.

10/ Iron production measured as shipments of iron and steel products plus castings corrected for imported ingots and blooms. Secondary production measured as reported consumption. Apparent supply includes production of raw steel. Monetary value based on U.S. annual average composite price for No. 1 heavy melting steel calculated from prices published in American Metal Market.

11/ Lead processors are segregated by primary and secondary producers. This segregation permits inclusion of stocks changes for secondary producers. Monetary value of scrap and apparent supply estimated upon average quoted price of common lead.

12/ Includes magnesium content of aluminum-base scrap. Monetary value based on the annual average Platt's Metals Week's U.S. spot Western price.

13/ Scrap is nickel contained in scrap consumed by producers of stainless and alloy steels, supperalloys, and aluminum-base, copper-base, or nickel-base alloys. Monetary value based on annual average LME cash price of nickel cathode.

14/ Monetary value based on Platt's Metals Week Composite price for tin.

15/ Percent recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.

16/ Monetary value based on annual average Platt's Metal Week metal price for North American special high grade zinc.

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RHENIUM

By John W. Blossom

In the past decade, the two most important uses of rhenium have been in platinum-rhenium catalysts used primarily in producing lead-free, high-octane gasoline and in high-temperature superalloys for jet engine components. Other uses of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, though smaller in quantity, are more diverse. These include use in thermocouples, heating elements, temperature controls, flashbulbs, vacuum tubes, X-ray tubes and targets, metallic coatings, and electrical contact points. Research by industry continues on rhenium recovery from ore and concentrate and on development of new catalysts and alloys.

U.S. rhenium is a byproduct of molybdenite recovered as a byproduct of porphyry copper ore from eight operating porphyry copper-molybdenum-rhenium mines in the Western States. Domestic mine production data for rhenium were derived by the U.S. Geological Survey from reported molybdenum production at the mines. Domestic demand for rhenium metal and other rhenium products was met by domestic recovery, domestic stocks, and imports, the principal source of supply.

Consumption of rhenium increased about 49%, and imports for consumption increased 62%. The major increases in consumption were in bimetallic platinum-rhenium catalysts and high-temperature jet engine components. The average prices for metal powder and ammonium perrhenate were $900 per kilogram, respectively.

Consumption

Rhenium is used in petroleum-reforming catalysts for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Rhenium catalysts tolerate greater amounts of carbon formation and make it possible to operate at lower pressures and higher temperatures, which leads to improved yields and octane ratings. Catalytic units with platinum-rhenium catalysts are used in about 80% of total U.S. reforming capacity. Platinum-rhenium catalysts also are used in the production of benzene, toluene, and xylenes, although this use is small compared with that of gasoline production.

A significant property of rhenium is its ability to alloy with molybdenum and tungsten. Molybdenum alloys containing about 50-weight-percent rhenium have greater ductility and can be fabricated by either warm or cold working. Unlike other molybdenum alloys, this alloy is ductile, even at temperatures down to 196° C, and can be welded. Alloys of tungsten with 24-weight-percent rhenium have improved ductility and have lower ductile-to-brittle transition temperatures than pure tungsten. Rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). Some of the uses for these alloys, which represented only 10% of total demand, are in thermocouples, temperature controls, heating elements, ionization gauges, mass spectrographs, electron tubes and targets, electrical contacts, metallic coatings, vacuum tubes, crucibles, electromagnets, and semiconductors.

Foreign Trade

Imports for consumption of ammonium perrhenate came from Chile, France, Germany, Kazakstan, Russia, the United Kingdom, and Uzbekistan, and rhenium metal came from Chile, Germany, Kazakstan, Russia, and the United Kingdom. World production of rhenium in ore was estimated to be 50 metric tons; the quantity of rhenium actually recovered is, however, much lower because not all concentrates are processed to recover the rhenium values. Rhenium was recovered from some byproduct molybdenite concentrates from porphyry copper deposits in Canada, Chile, China, Iran, Kazakstan, Peru, Russia, and the United States. Rhenium metal and compounds were recovered from molybdenum concentrates in Chile, France, Germany, Russia, the United Kingdom, and the United States.

World Review

World reserves of rhenium are contained primarily in molybdenite in porphyry copper deposits. U.S. reserves of rhenium are concentrated in Arizona and Utah but also are found in Montana, Nevada, and New Mexico. Canadian reserves are in British Columbia, primarily on Vancouver Island. Chilean reserves are found primarily at four large porphyry copper mines and in lesser deposits in the northern one-half of the country. In Peru, reserves are concentrated primarily in the Toquepala open-pit porphyry copper mine and in about 12 other deposits in the rest of the country.

Other world reserves are in several porphyry copper deposits and one sedimentary copper deposit in the south-central part of the former Soviet Union between the Caspian Sea and northwestern China, in Europe, and in sedimentary copper-cobalt deposits in Zaire.

Outlook

In the next 5 years, increased demand for rhenium metal will follow the demand for aircraft engines and for petroleum. For the long term (10 to 20 years), recycling of rhenium-bearing waste and scrap must be greatly improved. Identified U.S. resources are estimated to be about 5,000 metric tons, and identified rest-of-world resources are about 6,000 tons.

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TABLE 1
SALIENT U.S. RHENIUM STATISTICS 1/

(Kilograms)

	1992	1993	1994	1995	1996
Mine production 2/	16,000	12,200	15,500	17,000	14,000
Consumption e/	6,800	6,900	12,900	16,200	24,100
Imports (metal)	6,390	2,700	5,870	9,550	10,800
Imports (ammonium perrhenate)	5,690	3,170	2,330	3,280	10,000

e/ Estimated.

1/ Data are rounded to three significant digits.

2/ Calculated rhenium contained in molybdenite concentrates.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY 1/

	1995		1996	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	776	$627	--	--
Chile	3,600	3,180	8,500	$7,960
Germany	2,510	1,790	1,730	1,380
Kazakstan	2,580	1,430	50	26
Russia	--	--	425	102
United Kingdom	88	29	100	39
Total	9,550	7,050	10,800	9,500

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY 1/

	1995		1996	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Chile	1,120	$558	5,280	$2,100
France	--	--	278	12
Germany	773	340	1,090	310
Kazakstan	--	--	628	147
Kyrgyzstan	89	27	--	--
Russia	744	184	871	322
United Kingdom	551	121	1,500	441
Uzbekistan	--	--	350	105
Total	3,280	1,230	10,000	3,440

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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SALT

By Dennis S. Kostick

Salt, also known as sodium chloride, an important commodity, has many end uses. Virtually every person in the world has some daily contact with salt either directly or indirectly. People routinely add salt to their food as a flavor enhancer or apply rock salt to walkways to remove ice in the winter. Salt is used as feedstock for chlorine and in the manufacture of caustic soda. These two important inorganic chemicals are used to make a multitude of consumer-related end-use products, such as polyvinyl chloride (PVC) plastic made from chlorine and paper pulping chemicals manufactured from caustic soda.

Production

U.S. production data for salt are developed by the U.S. Geological Survey (USGS) from an annual voluntary survey of U.S. salt-producing sites and of company operations. Of the 28 companies to which a survey request was sent, all but one responded, representing 97% of the total production shown in this report. Data for the one company were estimated on the basis of its prior responses to previous annual surveys, the 1996 production estimate survey, or brine production capabilities for chloralkali manufacture based upon chlorine production capacities.

Total U.S. salt production increased slightly in 1996 compared with the previous year. Rock salt production decreased 4%; however, domestic inventories of rock salt rose because imports increased in anticipation of adverse winter weather. The lower level of rock salt production, as compared with previous years' levels, also was a result of losing the Akzo Nobel Salt Inc.'s rock salt mine that normally produced nearly 3.6 million metric tons of salt per year. Solar salt production declined 8%, mainly in the bulk salt category. According to the USGS canvass for 1996, 28 companies operated 64 salt-producing plants in 14 States. Two of the plants had closed but continued to sell from inventory during 1996. Seven of the companies and 12 of the plants produced more than 1 million tons each and accounted for 87% and 62%, respectively, of the U.S. total production and 94% and 31%, respectively, of total value. Several companies and plants produced more than one type of salt. In 1996, 12 companies (16 operations) produced solar-evaporated salt; 5 companies (16 operations), vacuum pan salt; 10 companies (13 operations), rock salt; and 13 companies (27 operations), salt brine. *(See tables 1, 2, and 3.)*

The five leading States in terms of total salt sold or used were Louisiana, 33%; Texas, 24%; New York, 11%; Kansas, 7%; and Utah, 4%. Although Louisiana, New York, and Ohio were major rock salt-producing States, a substantial amount of salt was produced in Alabama, Kansas, Louisiana, New York, Ohio, Texas, Utah, and West Virginia as brine for the chemical industry. *(See table 4.)*

U.S. salt production accounted for about 22% of total world production. Production and trade of salt remained about the same as that of 1995. Total world production of all types of salt was essentially the same as the previous year. The depressed market for chlorine and environmental problems associated with emissions of chlorinated compounds may affect the short-term status of the world chloralkali industry, which is the largest single consumer of salt.

Akzo Nobel Salt Inc. sold its Manistee, MI, vacuum pan salt facility to Ambar Inc., which is based in Lafayette, LA. Ambar will convert the plant and produce 300,000 tons per year of calcium chloride. Brine feedstock will be supplied by Martin Marietta Magnesia located nearby (Industrial Minerals, 1996).

Akzo Nobel NV, the parent company of Akzo Nobel Salt Inc., announced on April 22 that it would not construct a new rock salt mine at Hampton Corners, NY, because the project did not meet its financial criteria. About $120 million to $140 million would had to have been invested in the project, which would have produced rock salt for the unpredictable deicing market. Akzo retained the Retsof location as a salt distribution center that would be supplied by its Cleveland, OH, mine (Akzo Nobel, 1996).

Almost 4 months later on August 15, Cargill Inc. of Minneapolis, MN, and Akzo Nobel NV of the Netherlands announced that Cargill would purchase the North American (excluding the flooded Retsof mine and distribution center) and Caribbean salt operations from Akzo's U.S. subsidiary, Akzo Nobel Salt Inc. Akzo had annual U.S. sales of about $450 million, while Cargill's annual sales were estimated between $150 million to $200 million. The transaction included Akzo's corporate offices in Clarks Summit, PA; rock salt mines at Cleveland, OH, and Avery Island, LA; vacuum salt plants in St. Clair, MI, Watkins Glen, NY, and Akron, OH; and solar salt facilities in Timpie, UT, and on the island of Bonaire in the Netherlands Antilles in the Caribbean. Solar salt terminals in Port Newark, NJ, and Cape Canaveral, FL, were also includedin the transaction. These operations will be added to Cargill's assets which include solar salt plants at Amboy, CA, Newark, CA, Redwood City, CA, Freedom, OK, and Port Hedland, Australia; vacuum pan salt plants at Newark, CA, Hutchinson, KS, Breaux Bridge, LA, and Watkins Glen, NY; and a rock salt mine in Lansing, NY. After the acquisition, Cargill will have a worldwide annual production capacity of 8 million tons of rock salt, 2 million tons of vacuum pan salt, and 2.5 million tons of solar salt (Chemical Marketing Reporter, 1996a).

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United Salt Corp. and Market Hub Partners Limited Partnership formed a joint venture to solution mine the salt deposit near Tioga, PA. United planned to construct an evaporated salt facility that would have an annual capacity of about 450,000 tons, the majority of which would be marketed in the region in 1998. Market Hub Partners planned to use the resulting caverns to store hydrocarbons. (Chemical Marketing Reporter, 1996b)

Consumption

A record 52.8 million tons of domestic and imported salt was consumed in the United States in 1996, based on the annual survey of the U.S. salt producers. This represented an increase of 14% compared with that of the previous year. The 1996 reported percent distribution of salt by major end use was chemicals, 42%; ice control, 33%; distributors, 9%; food and agricultural, 3% each; industrial, 7%, primary water treatment, 1%; and other combined with exports, 2%. Distributors represent a substantial share of salt sales by the salt industry; however, all the salt ultimately is resold to many end users. Some customers have specific uses for salt. For a more complete analysis of end-use markets, specific sectors of distribution in table 5 can be combined, such as agricultural and water conditioning with agricultural and water conditioning distribution, respectively.

The chemical industry consumes the majority of the salt produced, primarily salt brine. Although most salt brine is captively produced by chemical producers, many chloralkali manufacturers now purchase brine from independent brine supply companies. In certain cases, brine is captively produced by one chemical company, and any excess brine is sold to neighboring competitors. About 48% of the salt used to manufacture chlorine was captive and 31% was purchased brine. Rocks salt, solar salt, and vacuum pan salt are also used to manufacture many chemicals. *(See tables 5 and 6.)*

According to the Bureau of the Census data, 11.5 million tons of chlorine and 10.7 million tons of sodium hydroxide were produced in 1996 (Bureau of the Census, 1997). Based on the industry average ratio of 1.75 tons of salt required to produce 1.0 ton of chlorine and 1.1 tons of coproduct sodium hydroxide, the chlorine and caustic soda industry consumed about 20 million tons of salt for feedstock. Reported consumption of total domestic and imported salt for chlorine manufacture was 19.7 million tons, as shown in table 5. The difference between the calculated and reported quantities was the amount of salt unreported to the USGS from imports or captive brine production of chloralkali producers.

Salt for human consumption is packaged in different sized containers for several specialized purposes. Table salt may contain 0.01% potassium iodide as an additive that provides a source of iodine that is essential to the oxidation processes in the body. Kosher salt, seasalt, condiment salt, and salt tablets are special varieties of salt.

Water conditioning and animal feed salt are made into 22.7-kilogram (50-pound) pressed blocks. Sulfur, iodine, trace elements, and vitamins are occasionally added to salt blocks to provide missing nutrients not found naturally in the diet of certain livestock. Salt is also compressed into pellets and used for water conditioning.

There are reportedly about 14,000 different direct and indirect uses of salt. The USGS annually surveys 8 major categories comprising 29 separate end uses.

Chemical.—The greatest quantity of salt used in the chemical industry is by the chloralkali sector. Traditionally, the chloralkali sector included salt consumed for chlorine, coproduct sodium hydroxide (also known as caustic soda and lye), and synthetic soda ash. Since 1986 when the last synthetic soda ash plant closed because of high production costs and competition with less expensive natural soda ash, no synthetic soda ash has been manufactured in the United States; however, many countries still produce synthetic soda ash and use vast quantities of salt brine as feedstock.

Salt is used as the primary raw material in chlorine manufacture because it is an inexpensive and widely available source of chlorine ions. For sodium hydroxide production, salt is the main source of the sodium ions. About 98% of the domestic chlorine and sodium hydroxide produced is obtained from the electrolysis of salt brine feedstock using three different cell technologies. The types of cells and percent chlorine manufactured by them are diaphragm, 78%; mercury, 14%; and membrane, 6%.

It takes about 1.75 tons of salt to make 1.0 ton of chlorine and 1.1 tons of coproduct caustic soda. The electrolytic process ionizes the sodium chloride compound and selectively allows the ions to migrate through special membranes. Chlorine gas forms at the anode while sodium ions bond with water molecules at the cathode to form sodium hydroxide with hydrogen gas evolving.

Chlorine and caustic soda are considered to be the first generation of products made from salt. These two chemicals are further used to manufacture other materials, which are considered second generation products from salt. Salt is also used as a feedstock in chemical establishments that make sodium chlorate (by the electrolysis of an acidified salt brine using hydrochloric acid adjusted to a pH of 6.5), metallic sodium (by the electrolysis of a molten salt mixture containing 33.2% sodium chloride and 66.8% calcium chloride, which is added to reduce the melting temperature of salt), and other downstream chemical operations. In powdered soaps and detergents, salt is used as a bulking agent and as a coagulant for colloidal dispersion after saponification. In pharmaceuticals, salt is a chemical reagent and is used as the electrolyte in saline solutions. It is also used as a cofeedstock with sulfuric acid to produce sodium sulfate and hydrochloric acid. This subsector is relatively small, representing only 5% of domestic salt sales for the entire chemical sector and only 2% of total domestic salt consumption.

The consumption of salt for metallic sodium has declined over the past several years. Since the 1970s, the number of producers has decreased from three to one; Ethyl Corp. and RMI Titanium Corp. exited the market in about 1985 and 1992,

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respectively, leaving E.I. du Pont de Nemours & Co. as the sole manufacturer of metallic sodium in the United States. The domestic market was about 126,000 tons in 1978; whereas in 1992, it shrunk to only 30,000 tons. The phasing out of tetraethyl lead and tetramethyl lead gasoline additives were the main reasons for the decline in consumption. Sodium usage in gasoline represented about 80% of the domestic market in 1978. The largest use of sodium in 1992 was for sodium borohydride production, which is the feedstock for sodium dithionite, which is used as a reductive bleaching agent by the pulp and paper industry. Sodium for sodium borohydride manufacture accounts for about 33% of metallic sodium consumption (Chemical Marketing Reporter, 1996c).

Food Processing.—Every person uses some quantity of salt in their food. The salt is either added to the food by the food processor or by the consumer through free choice. Salt is added to food as a flavor enhancer, preservative, binder, fermentation control additive, texture aid, and color developer. This major category is subdivided into six applications, in descending order of salt consumption: meat packers, canning, other food processing, grain mill products, baking, and dairy.

In meatpacking, salt is added to processed meats to promote the color development in bacon, ham, and other processed meat products. As a preservative, salt inhibits the growth of bacteria, which would lead to spoilage of the product. Early pioneers used to store their perishables in salt barrels for protection and preservation. Salt acts as a binder in sausages to form a binding gel comprising meat, fat, and moisture. Salt also acts as a flavor enhancer and a tenderizer.

In canning, salt is primarily added as a flavor enhancer and preservative. It also is used as a dehydrating agent, tenderizer, enzyme inhibitor, and as a carrier for other ingredients.

In the "other food processing" category, salt is used mainly as a seasoning agent. Other food processing includes miscellaneous establishments that make food for human consumption (i.e., potato chips, pretzels) and domestic pet consumption (i.e., dog and cat food). In baking, salt is added to control the rate of fermentation in bread dough. It also is used to strengthen the gluten (the elastic protein-water complex in certain doughs) and as a flavor enhancer, such as a topping on baked goods. The food processing category is grain mill products, which consists of milling flour and rice, manufacturing cereal breakfast food, and blended or prepared flour.

In the dairy industry, salt is added to cheese as a fermentation control agent and as a color and texture control agent. The dairy subsector includes companies that manufacture creamery butter, natural and processed cheese, frozen desserts, ice cream, condensed and evaporated milk, and specialty dairy products.

General Industrial.—The industrial uses of salt are diverse. They include, in descending order of salt usage, oil and gas exploration; other industrial; textiles and dyeing; metal processing; pulp and paper; tanning and leather treatment; and rubber manufacture.

In oil and gas exploration, salt is an important component of drilling fluids in well drilling. It is used to flocculate and to increase the density of the drilling fluid in order to overcome high down-well gas pressures. Whenever drilling activities encounter salt formations, salt is added to the drilling fluid to saturate the solution and minimize the dissolution within the salt strata. Salt is also used to increase the set rate of concrete in cemented casings. In metal processing, salt is used in concentrating uranium ore into uranium oxide (yellow cake). It is also used in processing aluminum, beryllium, copper, steel, and vanadium.

In textiles and dyeing, salt is used as a brine rinse to separate organic contaminants, to promote "salting out" of dyestuff precipitates, and to blend with concentrated dyes to standardize them. One of its main roles is to provide the positive ion charge to promote the absorption of negatively charged ions of dyes.

In the pulp and paper industry, salt is used to bleach wood pulp. It also is used to make sodium chlorate, which is added along with sulfuric acid and water to manufacture chlorine dioxide--an excellent oxygen-base bleaching chemical. Although the chlorine dioxide process originated in Germany after World War I, it is becoming more popular because of environmental pressures to reduce or eliminate chlorinated bleaching compounds.

In tanning and leather treatment, salt is added to animal hides to inhibit microbial activity on the underside of the hides and to replace some of the moisture in the hides. In rubber manufacture, salt is used to make buna rubber, neoprene rubber, and white rubber. Salt brine and sulfuric acid are used to coagulate an emulsified latex made from chlorinated butadiene.

Agricultural Industry.—Since prehistoric times, humankind has noticed that animals satisfied their salt hunger by locating salt springs, salt licks, or playa lake salt crusts. Barnyard and grazing livestock need supplementary salt rations to maintain proper nutrition. Veterinarians advocate adding loose salt in commercially mixed feeds or in block forms sold to farmers and ranchers. Salt also acts as an excellent carrier for trace elements not found in the vegetation consumed by grazing livestock. Sulfur, selenium, and other essential elements are commonly added to salt licks, or salt blocks, for free-choice feeding.

Water Treatment.—Approximately 1.2 trillion liters (325 billion gallons) of water is used daily in the United States for residential and commercial uses. Many areas of the United States have "hard" water, which contains excessive calcium and magnesium ions that contribute to the buildup of a scale or film of alkaline mineral deposits in household and industrial equipment. Commercial and residential water-softening units use salt to remove the ions causing water hardness. The sodium ions captured on a resin bed are exchanged for the calcium and magnesium ions. Periodically, the water-softening units must be recharged because the sodium ions become depleted. Salt is added and dissolved, and the brine replenishes the lost sodium ions.

Ice Control and Road Stabilization.—The second largest end use of salt is for highway deicing. The developer of the Fahrenheit temperature scale (° F), discovered that salt mixed with ice (at a temperature below the freezing point) creates a solution with a lower freezing point than water by itself. The brine forms below the surface of the ice and snow and prevents

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the water from freezing into ice and bonding with the road surface. Therefore, salt causes snow and ice to melt. Salt is an inexpensive, widely available, and effective ice control agent. It does, however, become less effective as the temperature decreases below about -9.4° C to -6.7° C (15° F to 20° F). At lower temperatures, more salt would have to be applied to maintain higher brine concentrations to provide the same degree of melting. Most winter snowstorms and ice storms occur between -3.9° C to 0° C (25° F and 32° F), a range in which salt is most effective. An anticaking agent, such as ferric ferrocyanide (Prussian Blue) or sodium ferrocyanide (Yellow Prussiate of Soda), is used to prevent the salt from agglomerating. Both additives are nontoxic and harmless to humans. In fact, sodium ferrocyanide is approved for use in food-grade salt by the Federal Food and Drug Administration.

In highway deicing, salt has been associated with corrosion to motor vehicles, bridge decks, unprotected steel structures, and reinforcement bar and wire used in road construction. Surface runoff, vehicle spraying, and windblown actions also affect roadside vegetation, soil, and local surface and ground water supplies. Although there is evidence of environmental loading of salt during peak usage, the spring rains and thaws usually dilute the concentrations of sodium in the area.

Salt is also added to stabilize the soil and to provide firmness to the foundation on which highways are built. The salt acts to minimize the effects of shifting caused by changes in humidity and traffic load in the subsurface.

Distributors.—A tremendous amount of salt is marketed through various distributors, some of which specialize in certain markets such as agricultural and water-treatment services. In addition to these two categories, distributor sales include grocery wholesalers and/or retailers, institutional wholesalers, U.S. Government resale, and other wholesalers and retailers.

Stocks

Because bulk salt is stored at many different locations, such as at the plants, warehouses, ports, and terminals, data on the quantity of salt stockpiled by the salt industry is not reliable enough to formulate accurate inventory totals; however, yearend stocks of producers were estimated to be 3.0 million tons. Most of these inventories were imported rock salt and solar salt. Many salt producers, States, municipalities, distributors, and road-deicing contractors stockpiled additional quantities of salt in anticipation of adverse weather conditions. Deicing salt inventories were extremely large by yearend because the mild winter in the domestic snow belt did not require as much salt as had been stockpiled. For the reasons discussed above, salt stocks are assumed to be the difference between salt production and salt sold or used in calculating apparent consumption.

Transportation

The locations of the salt supplies often are not in proximity of the consumers location, and transportation can become an important cost. Pumping salt brine through pipelines is an economic means of transportation but cannot be used for dry salt. Large bulk shipments of dry salt in ocean freighters or river barges are low in cost, but are restricted in points of origin and consumption. River and lake movement of salt in winter is often severely curtained because of frozen waterways. As salt is packaged, handled, and shipped in smaller units, the costs are increased and are reflected in higher selling prices.

Oceanborne imports of salt have been increasing in some areas of the United States because they are less expensive with respect to transportation costs than what could be purchased from domestic suppliers using rail transportation.

Prices

The four types of salt that are produced each have unique production, processing, and packaging factors that determine the selling prices. Generally, salt sold in bulk is less expensive than salt that has been packaged, pelletized, or pressed. Salt in brine is the least expensive salt sold because mining and processing costs are less. Vacuum pan salt is the most expensive because of the higher energy costs involved in processing and the purity of the product.

Price quotations are not synonymous with average values reported to the USGS. The quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They are quoted here to serve only as a reference to yearend price levels. Yearend prices were quoted in Chemical Marketing Reporter, as shown in table 7. The average annual values, as collected by the USGS are shown in table 8 and represent a national average value for each of the types of salt and the various product forms. *(See tables 7 and 8.)*

Foreign Trade

Under the Harmonized Tariff Schedule nomenclature, imports are aggregated under one category classified as "Salt (including table and denatured salt) and pure sodium chloride, whether or not in aqueous solution, seawater." The same classification also applies to exports. The Harmonized System code for salt is 2501.00.0000. The trade tables in this report list the previous and current identification codes for salt. Although there are several other HS codes that pertain to various salt classifications, the United States aggregates the shipments under one code because the total of individual subclassifications fail to meet the minimum dollar requirements necessary for individual listings.

Based on Bureau of the Census statistics, the United States in 1996 exported 869,000 tons, a 30% increase compared with 1995. Salt was shipped to 67 countries through 33 U.S. customs districts; Cleveland, OH, district exported the most and represented 48% of the U.S. total. In 1996, the majority of exports, or 82% of the total, was to Canada. The Journal of Commerce's Port Import/Export Reporting Service (PIERS) which reports only ocean commerce (no rail or truck traffic between borders with Canada and Mexico) reported that seven

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domestic salt-producing companies accounted for 87% of the 484,000 metric tons exported in 1996. The companies, in descending order of shipments, were Akzo Nobel Salt Inc., Cargill Salt Co., Morton Salt Co., Western Salt Co., United Salt Co., North American Salt Co, and Redmond Minerals. Therefore, the remaining 13% of exports was by companies that do not produce salt.

The United States imported salt from 37 countries for a record 10.6 million tons in 1996, which was 50% more than was imported during the previous year. The large quantity of imports was to counter the shortage of rock salt supplies resulting from the September 1995 closure of Akzo's rock salt mine. The quantity of imports was about 12 times more than the quantity of salt that was exported. Although this would indicate that the United States is import reliant on salt to meet its salt requirements, the majority of imported salt was brought into the country by foreign subsidiaries of major U.S. salt producers. Generally, imported salt can be purchased and delivered to many customers at costs lower than the comparable domestic product because production costs are lower abroad, currency exchange rates are more favorable, and ocean freight rates are less expensive than overland rail or truck rates.

The PIERS service reported that 9.87 million tons of salt was imported. Census data and PIERS data are often dissimilar, and the discrepancy for 1996 is only 730,000 tons. Using PIERS data, Akzo Nobel Salt Inc., Cargill Inc., Morton International, and North American Salt Co. imported 68% of the total imports. Three companies that manufacture chlorine, which was the single largest domestic salt market, consumed 9% of total imports, which was primarily solar salt. The companies were Atochem North America, Occidental Chemical Corp., and Weyerhaeuser Co. Several salt distributors, including Continental Salt Co., Eastern Minerals, Granite State Minerals, Rochez Brothers, and Southern Salt Co., imported 18% of the total salt. The salt producers, salt distributors, and chloralkali producers imported 95% of total PIERS imports; the remainder was by many small direct buyers. Tables 9 through 12 list the import and export statistics reported by the Bureau of Census for 1995-96. *(See tables 9, 10, 11, and 12.)*

World Review

Table 13 lists world salt production statistics for 111 countries based on reported and estimated information. The reunification of Germany and the dissolution of the former Soviet Union, Czechoslovakia, and Yugoslavia in 1992 have modified the list of nations surveyed. Total world production remained the same in 1996 compared with that of 1995. *(See table 13.)*

The United States remained the world's leading salt-producing nation, representing about one-fifth of total world production. The structure of the U.S. industry has changed throughout the years. Based on an annual survey of the domestic salt industry by the former U.S. Bureau of Mines and the USGS, in 1970 there were 50 companies operating 95 plants in the United States. Market competition, energy and labor costs, less expensive imports, and an excess of production capacity resulting in the downsizing of the industry through mergers and acquisitions reduced the size of the industry to 28 companies and 64 plants by 1996.

Most countries possess some form of salt production capability with production levels set to meet their own domestic demand requirements with additional quantities available for export. Many developing nations tend to develop their agricultural resources first to feed their population. Development of easily extractable mineral resources follows with salt being one of the first commodities to be mined. Some countries, such as the United States, import a substantial amount of salt to meet total demand requirements because of economic factors.

Canada.—Harris Chemical North America Inc. announced on April 23 that it planned to increase production capacity from 4.5 million tons to 6.5 milliion tons at its Goderich rock salt mine in Ontario. The $12-million project was scheduled for completion by March 1997. Notice of the expansion came after Akzo announced it would not seek to build a replacement mine at Hamptons Corner, NY (North American Minerals News, 1996).

France.—Morton International purchased the solar salt facility owned by Compaigne des Salins du Mide et des Salines de l'Est for $290 million. This was Morton's first salt acquisition outside of North America. The solar salt plant produces nearly all of France's solar salt and about one-half of vacuum pan salt output. It also is the only producer of rock salt in the country (Wall Street Journal, 1997).

Outlook

Despite the loss of the Retsof Mine that occurred in late 1995, the United States will continue to have adequate sources of salt to satisfy its demand requirements. The supply of salt will come from increases in production capacity at other locations and imports from various salt resources in the Western Hemisphere. With the departure of Akzo Nobel Salt Inc. as a major salt producer in the United States and the Caribbean, the size of the domestic salt industry has shrunk in terms of the number of companies; however, the remaining companies will continue to provide salt to the domestic markets.

Salt consumption for chlorine production should remain stable for the near future despite efforts to reduce chlorine usage in the United States because of environmental concerns regarding chlorinated paper bleaching chemicals containing chlorine. As some countries close some of the small and inefficient synthetic soda ash plants, such as those that closed in the past few years in Belgium, Colombia, and Germany, consumption of salt feedstock will decline. Japan was scheduled to close two of its synthetic soda ash plants in 1996 and 1997 that use imported solar salt from Australia and Mexico. Salt producers in these countries will evaluate alternative markets to offset sales to the soda ash industry.

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TABLE 1
SALIENT STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Production total: 2/	36,000	39,200	40,100	42,100	42,200
Brine	17,600	18,100	18,000	20,600	21,500
Rock	11,400	14,300	15,100	14,000	13,500
Solar	3,220	2,960	3,020	3,540	3,270
Vacuum pan and open pan	3,810	3,860	3,960	3,950	3,920
Sold or used by producers	34,800	38,200	39,700	40,800	42,900
Value	$803,000	$904,000	$990,000	$1,000,000	$1,060,000
Exports	992	688	742	670	869
Value	$32,200	$34,800	$30,200	$34,400	$39,300
Imports for consumption	5,390	5,870	9,630	7,090	10,600
Value	$87,700	$100,000	$151,000	$114,000	$167,000
Consumption, apparent 3/	39,200	43,400	48,600	47,200	52,600
Consumption, reported	39,700	44,400	47,200	46,500	52,800
World Production	183,000 r/	187,000	191,000 r/	192,000 r/	192,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Excludes Puerto Rico.

3/ Sold or used plus imports minus exports.

TABLE 2
SALT PRODUCED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM 1/

(Thousand metric tons)

Product form	Vacuum pans and open pans	Solar	Rock	Brine	Total
1995					
Bulk	678	2,590	13,500	20,600	37,300
Compressed pellets	1,020	175	XX	XX	1,200
Packaged	1,990	694	494	XX	3,180
Pressed blocks	257	86	66	XX	409
Total	3,950	3,540	14,000	20,600	42,100
1996					
Bulk	738	1,920	12,900	21,500	37,100
Compressed pellets	1,020	284	XX	XX	1,300
Packaged	1,920	928	555	XX	3,410
Pressed blocks	246	134	67	XX	447
Total	3,920	3,270	13,500	21,500	42,200

XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 3
SALT SOLD OR USED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM 1/2/

(Thousand metric tons and thousand dollars)

Product form	Vacuum pans and open pans		Solar		Rock		Brine		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1995:										
Bulk	670	35,000	2,370	35,200	12,500	253,000	20,500	142,000	36,100	465,000
Compressed pellets	1,010	135,000	168	18,900	XX	XX	XX	XX	1,180	154,000
Packaged:										
Less-than-5-pound units	108	NA	1	NA	--	NA	XX	XX	109	XX
More-than-5-pound units	1,870	NA	686	NA	464	NA	XX	XX	3,020	XX
Total	1,980	265,000	686	45,400	464	30,600	XX	XX	3,130	341,000
Pressed blocks:										
For livestock	151	NA	68	NA	51	NA	XX	XX	270	XX
For water treatment	105	NA	15	NA	15	NA	XX	XX	135	XX
Total	256	26,200	82	7,690	66	6,470	XX	XX	405	40,300
Grand total	3,920	461,000	3,310	107,000	13,000	290,000	20,500	142,000	40,800	1,000,000
1996:										
Bulk	723	38,500	1,690	31,400	13,800	278,000	21,500	145,000	37,700	492,000
Compressed pellets	1 020	138,000	285	29,200	XX	XX	XX	XX	1 300	167,000
Packaged:										
Less-than-5-pound units	112	NA	(3/)	NA	--	NA	XX	XX	112	XX
More-than-5-pound units	1,800	NA	860	NA	587	NA	XX	XX	3,250	XX
Total	1 910	264,000	860	52,800	587	41,400	XX	XX	3 360	358,000
Pressed blocks:										
For livestock	102	NA	100	NA	66	NA	XX	XX	269	XX
For water treatment	147	NA	34	NA	--	NA	XX	XX	180	XX
Total	249	25,400	134	11,500	66	6,440	XX	XX	449	43,300
Grand total	3,900	466,000	2,970	125,000	14,500	325,000	21,500	145,000	42,900	1,060,000

NA Not available. XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ As reported at salt production locations. The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company. Because data do not include salt imported, purchased, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 5 and 6, which are derived from company totals.

3/ Less than 1/2 unit.

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TABLE 4
SALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/2/

(Thousand metric tons and thousand dollars)

State	1995		1996	
	Quantity	Value	Quantity	Value
Kansas	2,770	113,000	2,950	118,000
Louisiana	14,700	177,000	15,500	175,000
New York	4,480	185,000	4,420	203,000
Texas	9,110	85,000	9,700	88,900
Utah	2,160	54,800	1,720	70,400
Other Eastern States 3/	6,270	316,000	7,040	332,000
Other Western States 4/	1,370	68,500	1,490	73,400
Total	40,800	1,000,000	42,900	1,060,000
Puerto Rico e/	45	1,500	45	1,500

e/ Estimated.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company.

3/ Includes Alabama, Michigan, Ohio, and West Virginia.

4/ Includes Arizona, California, Nevada, New Mexico, and Oklahoma.

TABLE 5
DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES BY END USE AND TYPE 1/2/

(Thousand metric tons)

End use	Standard industrial classification	Vacuum pans and open pans		Solar		Rock		Salt in brine		Grand total 3/	
		1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Chemical:											
Chloralkali producers	2812	32	34	492	684	823	906	18,700	19,700	20,100	21,300
Other chemical	28 (excludes 2812, 2899)	378	378	279	178	291	458	136	91	1,090	1,110
Total		410	412	772	862	1,110	1,360	18,800	19,800	21,100	22,400
Food processing industry:											
Meat packers	201	228	238	62	44	119	125	(4/)	--	410	407
Dairy	202	112	116	5	5	4	4	--	--	122	126
Canning	2091, 203	194	202	86	86	51	49	2	--	332	336
Baking	205	143	157	1	1	12	11	--	--	155	169
Grain mill products	204 (excludes 2047)	109	105	8	3	57	50	--	--	174	158
Other food processing	206-208, 2047, 2099	230	210	30	30	33	48	1	1	293	288
Total		1,020	1,030	192	169	274	287	3	1	1,480	1,490
General industrial:											
Textiles and dyeing	22	219	210	48	53	18	18	5	7	290	288

See footnotes at end of table.

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TABLE 5-Continued
DISTRIBUTION OF DOMESTIC AND IMPORTED DATA BY PRODUCERS IN THE UNITED STATES
BY END USE AND TYPE 1/2/

(Thousand metric tons)

End use	Standard industrial classification	Vacuum pans and open pans		Solar		Rock		Salt in brine		Grand total 3/	
		1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
General industrial--Continued:											
Metal processing	33, 34, 35, 37	12	11	30	27	193	161	--	--	236	199
Rubber	2822, 30 (excludes 3079)	3	4	(4/)	1	3	4	60	63	67	71
Oil	13, 29	35	35	219	214	69	66	2,090	2,120	2,420	2,430
Pulp and paper	26	9	10	61	65	65	30	17	17	152	122
Tanning and/or leather	311	10	9	32	31	32	42	--	--	74	83
Other industrial	--	58	30	234	170	259	74	2	(4/)	552	275
Total		347	309	625	567	639	395	2,180	2,200	3,790	3,480
Agricultural:											
Feed retailers and/or dealers mixers	5159	223	273	373	387	446	491	--	--	1,040 r/	1,150
Feed manufactuers	2048	68	62	88	102	250	239	(4/)	--	407 r/	403
Direct-buying end user	02	9	6	12	12	44	47	--	--	66 r/	65
Total		300	340	474	502	740	777	(4/)	--	1,510 r/	1,620
Water treatment:											
Government (Federal, State, local)	2899	18	18	73	75	107	131	4	4	201	229
Commercial or other	2899	13	31	61	108	129	162	9	4	212	304
Total		30	49	134	183	235	293	13	8	413	534
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	2	9	512	1,300	11,300 r/	14,000	6	10	11,800 r/	15,300
Commercial or other	--	2	11	68	173	962	2,220	--	--	1,030 r/	2,400
Total		4	20	580	1,470	12,300	16,200	6	10	12,900 r/	17,700
Distributors:											
Agricultural distribution	5191	318	216	182	192	227	252	--	--	726	661
Grocery wholesalers and/or retailers	514, 54	539	535	232	221	76	99	--	--	847	855
Institutional wholesalers and end users	58, 70	84	118	28	36	26	30	(4/)	(4/)	139	184
Water-conditioning distribution	7399	135	163	356	485	72	72	--	--	563	719
U.S. Government resale	9199	1	(4/)	3	1	7	1	--	--	11	2
Other wholesalers and/or retailers	5251	680	724	597	694	635	807	(4/)	(4/)	1,910	2,230
Total		1,760	1,760	1,400	1,630	1,040	1,260	(4/)	1	4,200	4,650
Other n.e.s. 5/		169	139	155	169	661	463	95	118	1,080	889
Grand total		4,030	4,060	4,330	5,550	17,000	21,100	21,100	22,100	46,500	52,800

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ The quality of imports included in the total for each type of salt is the amount report by the U.S. salt industry, not the quantity reported by the U.S. Bureau of the Census that appears in tables 1, 11 and 12.

3/ Because data include salt imported, produced, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 1, 3, and 4, which are derived from plant reports at salt production locations. Data may differ from totals show in table 6 because of changes in inventory and/or incomplete data reporting.

4/ Less than 1/2 unit.

5/ Includes exports.

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TABLE 6
DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT
IN THE UNITED STATES, BY DESTINATION 1/2/

(Thousand metric tons)

Destination	1995				1996			
	Evaporated				Evaporated			
	Vacuum pans and open pans	Solar	Rock	Total	Vacuum pans and open pans	Solar	Rock	Total
Alabama	59	1	86	146	58	1	74	133
Alaska	(3/)	5	(3/)	5	(3/)	4	(3/)	4
Arizona	47	93	3	143	49	101	2	151
Arkansas	46	2	64	112	46	2	91	140
California	146	758	2	906	148	761	2	911
Colorado	12	80	53	145	15	85	119	218
Connecticut	11	20	125	156	10	89	120	220
Delaware	3	6	13	22	3	6	30	39
District of Columbia	(3/)	1	3	4	(3/)	2	10	13
Florida	70	147	42	259	68	167	22	257
Georgia	63	65	52	180	69	80	65	215
Hawaii	1	2	--	3	1	3	(3/)	4
Idaho	9	94	3	106	10	99	3	112
Illinois	302	160	1,460	1,920	307	176	1,370	1,860
Indiana	212	79	674	965	219	68	728	1,020
Iowa	182	76	478	736	195	73	499	767
Kansas	73	38	329	440	78	40	377	494
Kentucky	57	7	417	481	61	9	727	797
Louisiana	45	2	330	377	46	2	580	628
Maine	9	3	178	190	9	11	654	674
Maryland	72	94	234	400	69	293	199	561
Massachusetts	33	10	352	395	34	39	226	299
Michigan	240	26	1,550	1,810	230	35	1,790	2,060
Minnesota	155	192	941	1,290	149	199	757	1,100
Mississippi	23	1	241	265	22	1	219	242
Missouri	114	44	522	680	103	45	630	778
Montana	1	44	3	48	1	48	3	52
Nebraska	72	38	158	268	72	38	169	280
Nevada	2	247	14	263	2	269	12	283
New Hampshire	5	62	99	166	6	95	98	200
New Jersey	124	197	225	546	129	400	300	829
New Mexico	8	47	1	56	11	53	(3/)	65
New York	202	58	2,300	2,560	213	111	2,930	3,250
North Carolina	211	65	70	346	190	137	109	436
North Dakota	5	39	9	53	6	20	5	30
Ohio	379	39	1,950	2,370	380	42	2,390	2,810
Oklahoma	31	20	68	119	34	19	96	150
Oregon	13	131	1	145	14	129	1	143
Pennsylvania	196	99	1,350	1,640	194	138	1,990	2,320
Rhode Island	10	36	9	55	8	169	23	200
South Carolina	48	11	8	67	58	12	9	79
South Dakota	29	45	34	108	27	59	37	122
Tennessee	71	4	552	627	64	4	690	758
Texas	184	138	225	547	207	155	211	572
Utah	8	247	43	298	8	433	27	468
Vermont	6	1	193	200	4	1	67	72
Virginia	88	81	158	327	81	91	404	576
Washington	30	501	(3/)	531	29	451	1	481
West Virginia	12	2	186	200	13	2	289	305
Wisconsin	233	100	918	1,250	196	143	1,290	1,630
Wyoming	(3/)	24	2	26	(3/)	23	2	25
Other 4/	78	46	288	412	109	92	363	564
Total 5/	4,030	4,330	17,000	25,400	4,060	5,550	21,100	30,700

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Each salt type includes domestic and imported quantities. Brine is excluded because brine is not shipped out of State.

3/ Less than 1/2 unit.

4/ Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, and some shipments to unspecified destinations.

5/ Because data include salt imported, purchased, and/or sold from inventory from regional distribution centers, evaporated and rock salt distributed by State may differ from totals shown in tables 1 and 3, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 5 because of changes in inventory and/or incomplete data reporting.

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TABLE 7
SALT YEAREND PRICES

	1995	1996
Salt, evaporated, common: 80-pound bags, carlots or truckloads:		
North, works, 80 pounds	$4.02	$4.02
Bulk, same basis, per ton	60.00-61.20	60.00-61.20
Salt, chemical grade, same basis: North, works, 80 pounds	4.30	4.30
Salt, rock, medium, coarse:		
Same basis, 80 pounds	2.70	2.70
Bulk, same basis, per ton	18.00-25.00	18.00-25.00
Sodium chloride, U.S.P.: Granular bags, per pound	.29	.29

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. v. 249, no. 1, Jan. 1, 1996, p. 32; and v. 251, no. 1, Jan. 6, 1997. p. 28.

TABLE 8
AVERAGE VALUE OF SALT, BY PRODUCT FORM AND TYPE 1/

(Dollars per metric ton)

Product form	Vacuum pans and open pans	Solar	Rock	Brine
1995:				
Bulk	$52.24	$14.84 r/	$20.16	$6.91
Compressed pellets	133.07	112.71	XX	XX
Packaged	133.72	66.06	66.04	XX
Average 2/	118.63	30.82 r/	21.80	6.91
Pressed blocks	102.26	93.35	97.48	XX
1996:				
Bulk	53.26	18.56	20.09	6.72
Compressed pellets	135.14	102.45	XX	XX
Packaged	138.22	61.38	70.47	XX
Average 2/	120.54	39.97	22.14	6.72
Pressed blocks	101.89	85.57	97.03	XX

r/ Revised. XX Not applicable.

1/ Net selling value, f.o.b. plant, excluding container costs.

2/ Salt value data previously reported were an aggregate value per ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented that is based on the aggregated values and quantities of the product form for each type of salt shown in table 3.

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TABLE 9
U.S. EXPORTS OF SALT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Bahamas, The	1	209	1	239
Bahrain	(2/)	80	1	331
Belgium	1	85	(2/)	39
Brazil	1	370	2	386
Canada	558	24,000	710	23,300
Chile	1	39	(2/)	88
China	2	115	(2/)	85
Colombia	(2/)	168	1	242
Dominican Republic	(2/)	97	1	385
El Salvador	1	117	1	126
Finland	1	85	1	65
France	2	108	2	163
Honduras	1	127	3	452
Hong Kong	(2/)	42	2	81
India	1	120	2	64
Indonesia	(2/)	36	25	1,220
Japan	2	633	3	546
Korea, Republic of	21	635	(2/)	288
Kuwait	(2/)	111	1	136
Malaysia	(2/)	34	2	77
Mexico	36	2,120	64	2,770
Netherlands	(2/)	22	2	868
Pakistan	--	--	1	34
Panama	1	69	1	112
Peru	2	78	1	87
Philippines	1	47	(2/)	17
Saudi Arabia	5	882	17	1,790
Singapore	21	1,170	7	662
Suriname	1	159	1	127
Sweden	(2/)	75	1	135
Taiwan	(2/)	243	1	253
United Arab Emirates	1	168	1	200
United Kingdom	2	236	1	337
Venezuela	1	833	9	1,780
Other	6 r/	1,090 r/	4	1,780
Total	670	34,400	869	39,300

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 10
U.S. EXPORTS OF SALT, BY CUSTOMS DISTRICT 1/

(Thousand metric tons and thousand dollars)

District	1995		1996	
	Quantity	Value	Quantity	Value
Anchorage, AK	(2/)	15	(2/)	51
Baltimore, MD	(2/)	181	1	197
Buffalo, NY	95	4,830	54	4,770
Charleston, SC	(2/)	95	1	190
Chicago, IL	(2/)	11	(2/)	39
Cleveland, OH	324	8,800	480	8,740
Columbia-Snake, OR	(2/)	18	(2/)	36
Detroit, MI	29	3,520	37	3,440
Duluth, MN	(2/)	29	1	58
El Paso, TX	1	78	5	228
Great Falls, MT	5	359	9	658
Houston, TX	5	1,940	18	3,240
Laredo, TX	32	1,890	53	2,340

See footnotes at end of table.

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TABLE 10--Continued
U.S. EXPORTS OF SALT, BY CUSTOMS DISTRICT 1/

(Thousand metric tons and thousand dollars)

District	1995		1996	
	Quantity	Value	Quantity	Value
Los Angeles, CA	32	2,290	35	3,200
Miami, FL	3	477	3	654
Minneapolis, MN	--	--	(2/)	4
Mobile, AL	1	64	1	223
New Orleans, LA	3	533	4	641
New York, NY	8	760	7	1,230
Nogales, AZ	2	70	1	58
Norfolk, VA	1	23	1	170
Ogdensburg, NY	7	863	5	698
Pembina, ND	1	164	3	286
Philadelphia, PA	(2/)	14	(2/)	25
Portland, ME	(2/)	35	(2/)	6
St. Albans, VT	(2/)	7	(2/)	22
St. Louis, MO	(2/)	16	(2/)	51
San Diego, CA	2	56	5	148
San Francisco, CA	23	1,130	34	874
San Juan, PR	(2/)	69	1	141
Savannah, GA	2	655	8	1,480
Seattle, WA	4	361	24	762
Tampa, FL	1	106	1	129
Other 3/	89	4,960	78	4480
Total	670	34,400	869	39,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Unknown, but assumed to be rail and/or truck shipments to Canada through various points of entry.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF SALT, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Australia	143	2,120	(2/)	45
Bahamas, The	896	11,900	1,240	16,400
Brazil	76	857	161	1,900
Canada	2,980	55,300	3,810	78,100
Chile	861	11,500	2,650	30,100
China	23	435	--	--
Dominican Republic	--	--	39	256
Egypt	29	360	69	722
France	2	752	15	1,010
Ireland	35	355	47	561
Israel	(2/)	252	1	146
Italy	15	364	(2/)	143
Japan	(2/)	138	2	120
Korea, Republic of	3	644	1	769
Mexico	1,660	22,200	2,170	30,600
Netherlands	59	1,770	48	1,440
Netherlands Antilles	158	2,580	80	1,500
Peru	--	--	96	859
Spain	144	1,380	136	1,130
Switzerland	(2/)	5	38	389
United Kingdom	1	136	33	497
Other	2	774	1	691
Total	7,090	114,000	10,600	167,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 12
U.S. IMPORTS OF SALT, BY CUSTOM DISTRICTS 1/

(Thousand metric tons and thousand dollars)

District	1995		1996	
	Quantity	Value	Quantity	Value
Anchorage, AK	15	247	17	218
Baltimore, MD	485	8,390	1,130	17,600
Boston, MA	486	5,920	854	10,900
Buffalo, NY	12	551	227	6,400
Charleston, SC	71	1,960	49	1,430
Chicago, IL	468	11,500	518	11,400
Cleveland, OH	109	2,390	268	5,440
Columbia-Snake, OR	378	5,570	425	5,670
Dallas-Fort Worth, TX	--	--	(2/)	9
Detroit, MI	1,160	21,000	1,080	20,300
Duluth, MN	228	3,700	224	3,990
El Paso, TX	--	--	(2/)	2
Great Falls, MT	1	73	1	86
Honolulu, HI	(2/)	7	--	--
Houston, TX	(2/)	93	1	380
Laredo, TX	1	146	1	129
Los Angeles, CA	118	2,220	115	2,350
Miami, FL	(2/)	29	(2/)	20
Milwaukee, WI	643	10,300	1,000	20,300
Minneapolis, MN	(2/)	49	1	9
New Orleans, LA	209	2,710	283	3,910
New York, NY	971	12,900	1,680	18,900
Norfolk, VA	76	1,140	222	2,960
Ogdensburg, NY	20	641	94	2,950
Pembina, ND	9	250	28	645
Philadelphia, PA	376	4,420	761	9,130
Portland, ME	519	7,540	662	8,270
Providence, RI	71	820	227	2,730
St. Albans, VT	3	296	53	1,450
St. Louis, MO	(2/)	16	(2/)	25
San Diego, CA	1	54	1	168
San Francisco, CA	(2/)	123	(2/)	123
San Juan, PR	8	391	9	442
Savannah, GA	56	860	90	1,180
Seattle, WA	316	3,970	312	4,120
Tampa, FL	237	3,330	193	2,740
Wilmington, NC	52	360	106	1,170
Total	7,090	114,000	10,600	167,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 13
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Afghanistan (rock salt) e/	12	13	13	13	13
Albania e/	5	10	10	10	10
Algeria (brine and sea salt)	180	179	178	178 e/	178
Angola e/	20	30	30	30	30
Argentina:					
Rock salt e/	-- r/	1	3 r/	1	1
Other salt	952	1,033	852 r/	986 r/	990
Total e/	952 r/	1,030	855 r/	987 r/	991
Armenia e/	50 r/	30 r/	30 r/	33 r/ 4/	26 4/
Australia (brine salt and marine salt)	7,693	7,737	7,685	8,148 r/	7,905 4/

See footnotes at end of table.

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TABLE 13--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Austria:					
Brine salt	662	695	701 r/	523 r/	600
Rock salt e/	1	1	1	1	1
Total e/	663	696	702 r/	524 r/	601
Azerbaijan e/	50	40	30	20	15
Bahamas, The e/	809 4/	850	900	900	900
Bangladesh (marine salt) e/ 5/	320	340	350	350	350
Belarus	360 e/	300 e/	263	1 r/	1 4/
Benin (marine salt) e/	(6/)	(6/)	(6/)	(6/)	(6/)
Bolivia e/	(6/)	(6/)	(6/)	5 4/	(6/) 4/
Bosnia and Herzegovina e/	70	50	50	50	50
Botswana 7/	54	98	186	208	200
Brazil:					
Marine salt	4,030	4,780	4,670	4,460 r/	4,500
Rock salt	1,231	1,400	1,373	1,340 r/	1,400
Total	5,261	6,180	6,043	5,800 r/	5,900
Bulgaria	1,000	650	1,300 r/	1,500 r/	1,600
Burkina Faso e/	7	7	7	7	7
Burma e/ 8/	260	260	260	260	260
Cambodia e/	40	40	40	40	40
Canada	11,171	10,900	11,700	10,957 r/	12,289 p/
Cape Verde e/	4	4	4	4	1
Chile	1,672	1,443	3,178	3,000 e/	3,000
China e/	28,100	29,500	29,700	29,800 r/	28,900
Colombia:					
Marine salt	317	199	358	282 e/	424 p/
Rock salt	230	201	207	268	153 p/
Total	547	400	565	550 e/	576 p/
Costa Rica (marine salt) e/	30 r/	31 r/	32 r/	32 r/	37
Croatia	29	30	22 r/	22 r/	19 4/
Cuba e/	185	185	175	180	180
Czech Republic e/ 9/	XX	180	180	180	180
Czechoslovakia 10/	200 e/	XX	XX	XX	XX
Denmark (sales)	528	591	634 r/	603 r/	600
Dominican Republic (rock salt) e/	12	12 4/	10	10 r/	10
Egypt	1,096	986	1,008	1,000 e/	1,000
El Salvador (marine salt) e/	20	30	30	30	30
Eritrea: 11/					
Marine salt e/	XX	25	206	253	198
Rock salt e/	XX	1	2	2	2
Total	XX	26	208	255	200 4/
Ethiopia: e/ 5/					
Marine salt	100	45	--	--	--
Rock salt	10	8	5	5	5
Total	110	53	5	5	5
France:					
Brine salt	1,651	1,310	1,658	1,491 r/	1,500
Marine salt	1,156	1,200 e/	1,123	1,473 r/	1,500
Rock salt	103	116 e/	143	165 r/	160
Salt in solution	3,206	4,355	4,612	4,410 r/	4,500
Total	6,116	6,980 e/	7,536	7,539 r/	7,660
Germany:					
Marine salt	571	558	801	800 e/	800
Rock salt and other	12,137	12,130	9,731	10,000 e/	10,000
Total	12,709 r/	12,688	10,532	10,800 e/	10,800
Ghana e/	50	50	50	-- r/	-- 4/
Greece	143 r/	175 r/	192 r/	200 r/ e/	200
Guatemala e/	46 r/	47 r/	48 r/	48 r/	48
Honduras e/	30	30	25	25	25
Iceland e/	4 4/	5	5	4	4
India: e/					
Marine salt	9,500	9,500	9,500	9,500	9,500
Rock salt	3 4/	3 4/	3	3	3
Total	9,500	9,500	9,500	9,500	9,500

See footnotes at end of table.

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TABLE 13--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Indonesia e/	630	650	650	670	670
Iran 12/	1,018	720	1,050	936	450
Iraq e/	250	300	300	250	250
Israel	1,102	1,122	1,120 e/	1,200 e/	1,200
Italy:					
Brine salt and rock salt	3,211	3,150	3,353 r/	2,952 r/	3,000
Marine salt, crude e/ 13/	610	580	600	600	600
Total	3,821	3,730	3,953 r/	3,552 r/	3,600
Jamaica	21	18	18	19 r/	20
Japan	1,405	1,378	1,387	1,400 e/	1,400
Jordan	56	26	26 e/	25 e/	25
Kenya (crude salt)	102 e/	75	71 r/	71 r/	72
Korea, North e/	590	590	600	600	600
Korea, Republic of e/	772 4/	750	760	770	770
Kuwait	1	41	45 e/	45 e/	45
Laos (rock salt) e/	8	8	8	8	8
Lebanon e/	3	3	3	3	4
Leeward and Windward Islands e/	1	1	1	1	1
Libya e/	12	12	12	12	12
Madagascar e/	30	30	30	30	30
Mali e/	5	5	5	5	6
Malta (marine salt) e/	(6/)	(6/)	(6/)	(6/)	(6/)
Martinique e/	200	200	200	200	200
Mauritania e/	6	6	6	6	6
Mauritius e/	6	6	6	6	6
Mexico	7,395	7,490	7,458	7,670	8,508 4/
Mongolia	1 r/	1 r/	(6/) r/	(6/) r/	(6/) 4/
Morocco (rock salt)	165	170	177	173 r/	168 4/
Mozambique (marine salt) e/	40	40	40	40	60
Namibia (marine salt) 14/	115	116	316	300 e/	300
Nepal 15/	7	7	7 e/	7 e/	7
Netherlands e/	3,628 4/	3,500	3,500	3,500	3,500
Netherlands Antilles	350 e/	300 e/	420 r/	424 r/	366 4/
New Zealand e/	80	80	80	50	60
Nicaragua (marine salt) e/	15	15	15	15	15
Niger e/	3	3	3	3	3
Pakistan: 5/					
Marine salt	10	14	13	17	18
Rock salt	853	895	847	935	940
Total	863	909	860	952	958
Panama (marine salt) e/	20	20	20	22	22
Peru e/	238 4/	238	238	238	238
Philippines (marine salt)	496	535	540 e/	540 e/	550
Poland:					
Rock salt	582	718	750	812 r/	800
Other salt	3,305	3,099	3,324	3,402 r/	3,360
Total	3,887	3,817	4,074	4,214 r/	4,163 4/
Portugal:					
Marine salt e/	125	125	125	-- r/	--
Rock salt	592	525	519	545	545
Total e/	717	650	644	545 r/ 4/	545
Romania:					
Rock salt	966	808	892	669 r/	350 4/
Other salt	1,590	1,380	1,310	1,820 r/	2,339 4/
Total	2,556	2,188	2,202	2,489 r/	2,689 4/
Russia e/	3,600	2,200	2,000	2,000	1,600
Senegal e/	110	117	117	120	120
Serbia and Montenegro	47	39	32	14 r/	22 4/
Sierra Leone e/	200	200	200	-- r/	100
Slovakia 9/	XX	70 e/	100 r/	100 r/	107 4/
Slovenia	9 r/	7 r/	8	8 e/	8
Somalia e/	1	1	1	1	2
South Africa 14/	702	613	414	313	253 4/

See footnotes at end of table.

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TABLE 13--Continued
SALT: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Spain:					
Marine salt and other evaporated salt	900 e/	900 e/	1,422 r/	1,282 r/	1,500
Rock salt	2,705	2,505	3,510 r/	3,494 r/	2,500
Total	3,610 e/	3,410 e/	4,932 r/	4,776 r/	4,000
Sri Lanka	122	43	56	60 e/	60
Sudan e/	75	75	75	75	50
Switzerland	276	221 r/	259 r/	399 r/	300
Syria	84	113	127	111 r/	115
Taiwan (marine salt)	26	176	186	221	233 4/
Tanzania	78 e/	18	17	7	7
Thailand:					
Rock salt	213	262	288	381	350
Other e/	100	100	100	100 4/	100
Total e/	313	362	388	481 4/	450
Tunisia (marine salt)	460	435	415	400 e/	478 4/
Turkey	1,418	1,426	1,353	1,444 r/	1,400
Turkmenistan e/	300 r/	300 r/	300 r/	277 r/ 4/	295 4/
Uganda e/	5	5	5	5	5
Ukraine e/	4,400	4,000	3,500	3,000	2,800
United Kingdom:					
Brine salt e/ 16/	1,200	1,200	1,300	1,300	1,300
Rock salt e/	1,500	1,500	1,700 4/	1,800	1,800
Other salt 16/	3,401	4,086	4,004	3,548 r/	3,600
Total e/	6,100	6,790	7,000	6,650 r/	6,700
United States including Puerto Rico:					
United States:					
Brine	17,600	18,100	18,000	20,600	21,500 4/
Rock salt	11,400	14,300	15,100	14,000	13,500 4/
Solar salt	3,220	2,960	3,020	3,540	3,270 4/
Vacuum pan salt	3,810	3,860	3,700	3,950	3,920 4/
Puerto Rico e/	45 4/	45	45	45	45
Total e/	36,100 4/	39,300	39,800	42,200 r/	42,300
Venezuela e/	318 4/	370	400	350 r/	350
Vietnam e/	350	350	375	375	375
Yemen	107	110	110	110 e/	110
Grand total	183,000 r/	187,000	191,000 r/	192,000 r/	192,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 11, 1997.

3/ Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available. Some salt brine production data for manufacture of chlorine, caustic soda, and soda ash are not reported because of incomplete data reporting by many countries.

4/ Reported figure.

5/ Year ending June 30 of that stated.

6/ Less than 1/2 unit.

7/ From natural soda ash production.

8/ Brine salt production as reported by the Burmese Government in metric tons, was as follows: 1992--46,509; 1993--58,915; 1994--58,612; 1995--81,156; and 1996--75,000 (estimated).

9/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

10/ Dissolved Dec. 31, 1992.

11/ Eritrea production was included in Ethiopia until independence in May 1993.

12/ Year begining Mar. 21 of that stated.

13/ Does not include production from Sardinia and Sicily, estimated at 200,000 metric tons annually.

14/ South Africa's decline and Namibia's increase in 1994 are due to production from Walvis Bay now included under Namibia.

15/ Year ending July 15 of that stated.

16/ Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brines; that captioned "Other salt" is the salt content of brines used for purposes other than production of salt.

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CONSTRUCTION SAND AND GRAVEL

By Wallace P. Bolen

Construction sand and gravel is one of the most accessible natural resources and a major basic raw material used mostly by the construction industry. Despite the low value of its basic products, the construction sand and gravel industry is a major contributor to and an indicator of the economic well-being of the Nation.

A total of 914 million metric tons of construction sand and gravel was produced in the United States in 1996; this was a slight increase compared with that of 1995. After a decrease in production in 1991, sand and gravel production increased for the following 5 consecutive years, an indication of the continuous strong demand for construction aggregates in the United States. *(See table 1.)*

Sand and gravel production increased during 1996 owing to continued growth in construction activity. Total construction activity advanced by 6% to $324.5 billion. This follows a 3% increase in 1995 and represents the fifth straight year of moderate increases for the construction industry (Rock Products, 1997). The construction industry is by far the largest consumer of sand and gravel.

The U.S. Geological Survey (USGS) surveyed 7,233 construction sand and gravel operations in the United States. Of these, 5,562 were active, 1,489 were idle, and 182 were either reported as or assumed to be permanently shut down. Of the 7,233 operations surveyed in 1996, 3,988, or 55.1%, responded to the USGS. The 3,988 respondents contributed 78% of the 914 million tons produced in 1996. The 5,562 operations were run by 3,838 companies with 8,109 active sand and gravel pits.

Foreign trade of construction sand and gravel remained minor in 1996. Exports increased nearly 18% to 1.5 million tons, but the value decreased by about 6% to $23.3 million, compared with those of 1995.

Imports increased about 13% to 1.26 million tons, and the value increased almost 32% to $15.8 million. Because imports and exports are small, domestic apparent consumption[1] of construction sand and gravel is essentially equal to U.S. production of 914 million tons.

Legislation

The Department of Transportation and Related Agencies Appropriation Act of 1997 (Public Law 104-205) was signed by the President on October 1, 1996. The Act appropriated a record highway funding of $20.3 billion, an increase of $313 million over that of fiscal year 1996. The Act also appropriated $1.46 billion for the Airport Improvement Program, an increase of $10 million over that of fiscal year 1996.

On December 13, 1996, the International Agency for Research on Cancer (IARC) upgraded crystalline silica inhaled in the form of quartz or cristobalite from occupational sources from Group 2A (probably carcinogenic to humans) to Group 1 (carcinogenic to humans). The IARC working group voted 10 to 7 in favor of the change. The group concluded that on the basis on a large number of epidemiological studies, evidence was sufficient in humans for the carcinogenicity of inhaled crystalline silica. The Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration use IARC reports to determine whether a substance should be covered by the Hazard Communication Standard. Products containing quartz or cristobalite will have to include a Material Safety Data Sheet stating the new Group 1 classification (Engineering and Mining Journal, 1997).

Other major issues of concern to the construction sand and gravel industry are the implementation of the Clean Air Act Amendments of 1990 and its complex legal and technical provisions; the amended Federal Water Pollution Control Act of 1977; the Clean Water Act, Section 404, dealing with "wetlands" and the associated "no net loss of wetlands" policy; the Storm Water Pollution Prevention Program; and the provisions of the Federal Endangered Species Act.

Production

U.S. production of construction sand and gravel was 914 million tons in 1996. Of the four major geographic regions, the West again led the Nation in the production of construction sand and gravel with 327 million tons, or 36% of the U.S. total. It was followed by the Midwest with 289 million tons, or 32%, the South with 202 million tons, or 22%; and the Northeast with 97 million tons, or 11%. Compared with that of 1995, production increased in all the major geographic regions except the Midwest, where production was virtually unchanged. *(See table 2.)*

Of the nine geographic divisions, the East North Central led the Nation in the production of construction sand and gravel with 192 million tons, or 21% of the U.S. total. It was followed by the Pacific with 169 million tons, or 18.4%, and the Mountain with 158 million tons, or 17.3%. *(See table 2 and figure 1.)* Compared with that of 1995, production increased in the following divisions: the New England, 7.1%; the East South Central, 5.9%; and the Pacific, 3%. The divisions with decreases were the Middle Atlantic, 3.4%, and the West South

[1]Apparent consumption is defined as production for consumption (sold or used) plus total imports minus total exports.

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Central, the West North Central, and the South Atlantic, slight. Production in the East North Central and the Mountain regions were unchanged from 1995.

A review of the production by size of operation indicates that 40.5% of the construction sand and gravel produced in 1996 came from 1,788 operations reporting between 100,000 and 499,999 tons per year, 25% came from 371 operations reporting between 500,000 and 999,999 tons per year, and 23.3% came from 151 operations reporting more than 1,000,000 tons per year. A total of 5,562 operations were active. At least 3.2%, or 182, of the operations active in 1995 where idled or shut down during 1996. *(See table 8.)*

The estimated production by quarters for 1996 indicates that most of the construction sand and gravel in the United States was produced in the third quarter and was followed by the second and the fourth quarters. *(See table 3.)* Estimated production by each quarter was also available for the majority of the States. *(See table 5.)*

Construction sand and gravel was produced in 1996 in every State. The 10 leading States were, in descending order of tonnage, California, Texas, Michigan, Ohio, Arizona, Washington, Illinois, Wisconsin, Minnesota, and Colorado. Their combined production represented 52% of the national total. Compared with that of 1995, production increased in 18 States, decreased in 14, and stayed about the same in 18. Of the top 10 States, production were virtually unchanged in 5, increased in 3, decreased in 2. *(See table 4.)*

In New Jersey, Amboy Aggregates Inc., South Amboy, has applied to the Minerals Management Service (MMS) for permission to mine sand in an area 3 to 45 nautical miles off the New Jersey coast. The application was made because of the shortage of available sand in the densely populated State. Some environmental groups and fisheries have responded negatively to the application. The MMS was set to begin the decisionmaking process in October after the comment period was closed (Engineering News Record, 1996d).

Limited information about the production of construction sand and gravel in foreign countries may be found in the USGS "Minerals Yearbook, Volume III, Area Reports: International." For nonreporting countries, estimates of sand and gravel and crushed stone outputs can be based on such indirect sources as the level of cement consumption.

In an industry with thousands of operating companies, status and ownership changes are many. Although it is not possible to review them all, a few noteworthy events follow.

Mineral Barexor began production of gold and construction sand and gravel at its Crescent Valley Gold Placer Mine in north-central Nevada. A wash plant, separator, and gold concentrator are expected to process 1,000 cubic yards per 10-hr shift of sand and gravel (Rock Products, 1996d).

Rogers Group has purchased the assets of Robinson Block Co. and Martinsville Sand and Gravel. Robinson Block's operations are in Bedford, IN, and Martinsville Sand and Gravel is in Morgan County, IN (Rock Products, 1996g).

Luck Stone, a producer of crushed stone, entered the sand and gravel business by acquiring Mechanicsville Sand and Gravel Co. from Powhatan Ready-Mix. Renamed Luck Sand and Gravel, the company expects to double production at the operation northeast of Richmond, VA (Rock Products, 1996e).

Denver-based Western Mobile purchased the ready-mix, concrete, sand, and gravel operations of Gosney and Sons Ready Mix Division of Bayfield, CO. Western Mobile's parent company, Redland Aggregates Ltd., Groby, Leicester, England, also plans to acquire additional aggregate operations in the United States (Rock Products, 1996k).

Bardon Group, United Kingdom, expanded its presence in the U.S. aggregates industry with the acquisition of E.L. Gardner's three ready-mix concrete plants and about 9 million tons of sand and gravel reserves in eastern Maryland (Rock Products, 1996b).

Irish-based CRH added to its holdings in the Northeastern United States by acquiring Tilcon from the British conglomerate BTR. Tilcon has 60 operations in Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont (Rock Products, 1996f).

Titan Resources announced it has acquired a commercial quarry located in southeastern Houston, TX. The new quarry marks Titan's entry into the commercial sand and gravel industry (Rock Products, 1996j).

Texas Industries added to its sand and gravel holdings by purchasing T.L. James and Co.'s Honey Island operation. Near Slidell, LA, the operation produces sand, gravel, clay, soil conditioners, and golf course materials (Rock Products, 1996i).

CAMAS Inc., the U.S. subsidiary of the British-based construction materials group, CAMAS plc, purchased Model Stone Co. Model Stone, based in Minneapolis/St. Paul, MN, has high-quality sand and gravel reserves and operations, a concrete block plant, and four ready-mix plants (Pit and Quarry, 1996).

Consumption

Construction sand and gravel reported by producers to the USGS is actually material that was "sold or used" by the companies and is defined as such. Stockpiled production is not reported until it is sold to a user or consumed by the producer. Because no consumption surveys are conducted by the USGS, the "sold or used" tonnage is assumed to represent the amount produced for domestic consumption and export. Because some of the construction sand and gravel producers did not report a breakdown by end use, their total production is reported under "Unspecified uses, actual." The estimated production of nonrespondents is reported under "Unspecified uses, estimated."

Of the 914 million tons of construction sand and gravel produced in 1996, 377 million tons, or 41.2% of the total, was unspecified uses. Of the remaining 537 million tons, 43.2% was used as concrete aggregates; 23.4%, for road base and coverings and road stabilization; 13.2%, as asphaltic concrete aggregates and other bituminous mixtures; 11.9%, as construction fill; 1.8%, for concrete products, such as blocks, bricks, pipes, etc.; 1.4%, for plaster and gunite sands; and the remainder, for snow and ice control, railroad ballast, roofing granules, filtration, and

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other miscellaneous uses. *(See table 6.)*

To provide a more-accurate estimation of the consumption patterns for construction sand and gravel, the "Unspecified uses" are not included in the aforementioned percentages. It is recommended that in any marketing or use pattern analysis, the quantities included in "Unspecified uses" be distributed among the reported uses by applying the previous percentages.

A review of consumption by major geographic regions indicates that most of the sand and gravel for concrete aggregates, including concrete sand, was used in the West, 36.4%; the South, 28.9%; and the Midwest, 25.5%; these regions have high levels of construction activity. Of the sand and gravel used for road base and coverings and for asphaltic concrete aggregates and other bituminous mixtures, 45.3% and 46.1%, respectively, were consumed in the West and 35.8% and 28.4%, respectively, in the Midwest. *(See table 7.)*

Additional information regarding production and/or consumption of construction sand and gravel by major uses in each State and the State districts is published in the USGS "Minerals Yearbook, Volume II, Area Reports: Domestic."

Recycling

The aggregates industry has been involved with recycling for several decades. Recently, recycling has become more important to aggregate producers, and the number of aggregate companies that are recycling has been increasing. Recycling in this industry generally refers to the crushing, screening, and reuse of cement and asphalt concretes. Aggregate and related asphalt and ready-mix companies are often involved at construction projects where they collect and reuse the materials at the site. Others collect materials from construction companies that haul the material to the recycler. The annual survey of construction sand and gravel producers now collects information on recycling of cement and asphalt concrete by sand and gravel companies. No information on recycling of these materials by the construction or demolition companies is collected by the USGS.

Asphalt Concrete.—A total of 3.74 million tons of asphalt concrete valued at $14.3 million was recycled by 160 companies in 37 States. This volume represents a 6.6% increase compared with that of 1995. *(See tables 14 and 15.)* Leading States were, in descending order of tonnage recycled, California, Washington, North Carolina, and Minnesota. Leading companies were, in order of volume produced, J.A. Jones Co., Granite Construction Co., CSR America, Inc., Lehman Brothers Co., and Aman Brothers, Inc.

Cement Concrete.—A total of 4.03 million tons of cement concrete valued at $15.1 million was recycled by 142 companies in 29 States. This volume represents a 12% increase compared with that of 1995. *(See tables 14 and 16.)* Leading States were, in descending order of tonnage recycled, Minnesota, California, and New York. Leading companies were, in order of volume produced, Premier Aggregates, Inc., Aman Brothers, Inc., Broad Hollow Estates, Inc., Danner, Inc., and CSR America, Inc.

Transportation

Information regarding the method of transportation of construction sand and gravel from the pit or processing plant to the first point of sale or use is available for each geographic region, as well as for the total United States. *(See table 11.)* Reports regarding the method of transportation were provided by the producers for 512 million tons, or 56% of the total U.S. production of construction sand and gravel. Of this total, 78% was transported by truck; 3.4%, by waterway; and 1.8%, by rail. A significant amount of construction sand and gravel produced, about 16.1%, was not transported, but was used at the production site. Because most producers did not either keep records or report shipping distances or cost per ton per mile, no transportation cost data were available.

Prices

Prices in this chapter are f.o.b. plant, usually at the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs, and profit.

Compared with that of 1995, the 1996 average unit price increased nearly 2.1% to $4.38 per ton. By use, the unit prices varied from a high of $5.77 for roofing granules to a low of $2.91 for fill. The largest increases were recorded for road stabilization (lime), 40.1%; road stabilization (concrete), 9.3%; and fill, 7.8%. Average unit prices declined for roofing granules, 21.2%; railroad ballast, 8%; and concrete products, 5.1%. *(See table 6.)*

Foreign Trade

The widespread distribution of domestic sand and gravel deposits and the high cost of transportation limits foreign trade mostly to local transactions across international boundaries. U.S. imports and exports are small, representing less than 1% of the domestic consumption.

Exports of construction sand increased by 37% to 1.16 million tons compared with that of 1995, but the value decreased by 5.5% to $18.1 million. Mexico was the major destination, receiving about 58% of the total, and was followed by Canada with 22%. Exports of construction gravel declined 19% to 368,000 tons, and the value decreased 7% to $5.16 million. Canada was the major destination, receiving about 85% of the total. *(See table 12.)*

Imports increased by about 13% to 1.26 million tons, and the value increased by about 32% to $15.8 million. Canada was the major source of imported construction sand and gravel with 76.5% of the total, and was followed by The Bahamas with 12.6%. *(See table 13.)*

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Current Research and Technology

The market for sand for winter road maintenance is being challenged by a new specially processed lightweight aggregate product developed and marketed by Western Aggregates near Denver, CO. The expanded shale product, called Realite Plus, is saturated with calcium or magnesium chloride and then coated with an asphaltic resin. The product is said to decrease significantly the amount of dust generated in spring cleanup and, owing to its weight, reduces transportation cost (Rock Products, 1996h).

A trial run for a new driverless highway is slated for 1997. The goal of the project is to show that off-the-shelf computers and sensors can be used to take highway driving out of the hands of motorists. The demonstration on a California freeway represents the second phase of a 7-year, $210 million program that aims to put a prototype automated highway into operation by 2010 (Engineering News Record, 1996b).

The U.S. Army Corps of Engineers (USACE) and the Federal Aviation Administration (FAA) are each developing new machines to simulate years of wear on highway and runway surfaces in just weeks or months. The testing allows researchers to try new asphalt, concrete, and various other mixes that are being considered for road and runway paving. Known generally as mobile automated loading machines, the machines can run for 24 hours a day, 7 days a week. Both agencies will spend millions of dollars designing, building, and operating the new machines and test facilities. The FAA and the California Department of Transportation are each already using mobile automated loading machines (Engineering News Record, 1996c).

Outlook

The demand for construction sand and gravel in 1997 is expected to be about 940 million tons, or about 2.8% more than that of 1996. The projected increases will be influenced by construction activity primarily in the public construction sector. Compared with that of fiscal year 1996, Federal spending for construction related programs were slated to increase in fiscal year 1997. Increases include USACE, 34%; transit, 8.8%; highways, 1.7%; airport grants, 1%; and Department of Energy cleanup, 1% (Engineering News Record, 1996e). The construction industry is expected to continue to grow in 1997 but at a slower rate. The rate of growth was predicted to drop to 3.5% in 1997 compared with 6% in 1996 (Engineering News Record, 1996f). Another forecaster predicted continued growth in sand and gravel production through 1999, with production reaching 1.04 billion tons in 1999 (Rock Products, 1996a).

The Great Basin Unified Air Pollution Control District in Bishop, CA, is likely to be a large consumer of gravel if plans for Owens Lake are approved. The lake dried as a result of water diversion to Los Angeles, and now the lake bed is adding to air-quality problems in California. The plans call for 14 square miles to be planted with vegetation, 13 square miles to be irrigated, and 8 square miles to be covered with about 37 million tons of gravel (Engineering News Record, 1997).

Construction sand and gravel f.o.b. prices are expected to increase only marginally, owing to a decrease in demand growth compared with the past several years. The delivered prices of construction sand and gravel are, however, expected to increase, especially in and near metropolitan areas, mainly because more aggregates are transported from distant sources. One estimate predicted that aggregate production and price would each increase by 2.7%. The report also estimated that prices will increase by 2.1% in 1998 and 2.5% in 1999 (Engineering News Record, 1996a).

For 1997, the industry is expected to continue to consolidate. Resistance to mining at the local level will push production to more rural areas and increase transportation cost. Acquisition cost will escalate because of the difficulty of starting a greenfield operation, which will allow resourceholders to demand higher prices for already permitted operations (Rock Products, 1996c).

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per year.

Mexico continued as the most important source for imported strontium compounds; Germany was second. Imports of strontium carbonate in 1996 were about the same as those in 1995, with imports from Mexico comprising 89% of total carbonate imports. Imports of strontium nitrate were 20% lower than those in 1995; strontium nitrate imports are extremely small when compared with imports of strontium carbonate. *(See tables 3 and 4.)*

World Review

In most instances, celestite deposits occur in remote, undeveloped locations far from population centers in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly occurs along with barium and calcium, two elements with chemical properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy intensive, current strontium chemical producers require material to contain at least 90% strontium sulfate. Most of the currently operating celestite facilities can produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use gravity separation, froth flotation, or other methods to beneficiate ore.

Leading celestite producers are Mexico, Spain, Turkey, and Iran, in decreasing order of importance. Significant quantities of celestite are produced in China and the former U.S.S.R.; however, not enough information is available to make any estimate of location, number, or size of mines. Celestite is produced in smaller quantities in Algeria, Argentina, and Pakistan.

Detailed information on most world resources is not readily available because very little information on exploration results has been published. Other deposits may be well identified but are in countries from which specific mineral information is not easily obtained.

Until World War II, practically all celestite produced worldwide was from the United Kingdom, and for several years following the end of the war, the United Kingdom maintained its importance. Depleted reserves, encroaching civilization, and the discovery of vast deposits in other countries resulted in the cessation of production in the United Kingdom. Any reported United Kingdom celestite production since 1992 was due to the reprocessing of mine tailings from the exhausted mine. *(See table 5.)*

Production facilities for strontium compounds and/or metal are located in Canada, China, Germany, Japan, the Republic of Korea, Mexico, Poland, the United States, and the former U.S.S.R.

Outlook

Sales of televisions and computer monitors in the United States continued at a high rate. Faceplate glass plants continued to operate at capacity and imports of glass continued. Because U.S. television glass producers are operating at capacity, domestic consumption of strontium carbonate for this end use will remain relatively level until additional glass capacity is installed. However, worldwide demand for strontium carbonate will increase to meet the demand for U.S. glass imports.

Growth in television sales is expected to continue and larger screens are expected to increase in popularity, and so demand for strontium carbonate for television application should expand. Growth in other markets will probably continue at their current, slower rate.

Development of a technology to produce an affordable flat television display could severely reduce the demand for strontium carbonate, but this is not expected in the near future. Although a high-quality, large, flat screen is not yet available, small models are, and research continues to seek improvements in the technology. The question remains whether a new display system can be developed that will be economically attractive to the general public. Initial devices are expected to find application in military hardware and other sophisticated medical and scientific instrumentation. Flat screen display systems may eventually replace cathode-ray tubes, and, at that point, strontium producers may experience a serious setback.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT CONSTRUCTION SAND AND GRAVEL STATISTICS 1/

		1992	1993	1994	1995	1996
Sold or used by producers:						
Quantity 2/	thousand metric tons	834,000 3/	869,000 e/ 3/	891,000	907,000 r/	914,000 3/
Value 2/	thousands	$3,340,000 3/	$3,530,000 e/ 3/	$3,740,000	$3,900,000 r/	$4,000,000 3/
Exports	value, thousands	$18,000	$15,600	$20,300	$24,700	$23,300
Imports	do.	$15,500	$15,400	$14,800	$12,000	$15,800

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits.
2/ Puerto Rico excluded from all sand and gravel statistics.
3/ Excludes Hawaii.

TABLE 2
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY
PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION 1/

	1995				1996			
Region/Division	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	37,800	4.2	$199,000	5.1	40,500	4.4	$202,000	5.0
Middle Atlantic	58,400	6.4	308,000	7.9	56,400	6.2	301,000	7.5
Midwest:								
East North Central	192,000	21.2	717,000	18.4	192,000	21.0	761,000	19.0
West North Central	97,000	10.7	315,000	8.1	96,500	10.5	324,000	8.1
South:								
South Atlantic	68,000	7.5	292,000	7.5	67,400	7.4	295,000	7.4
East South Central	40,400	4.5	171,000	4.4	42,800	4.7	182,000	4.5
West South Central	91,800	10.1	394,000 r/	10.1	91,700	10.0	402,000	10.0
West:								
Mountain	158,000 r/	17.4	681,000 r/	17.5	158,000	17.3	670,000	16.7
Pacific	164,000 r/	18.0	820,000 r/	21.0	169,000 2/	18.4	867,000 2/	21.7
Total	907,000 r/	100	3,900,000 r/	100	914,000	100	4,000,000	100

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes Hawaii.

TABLE 3
SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY QUARTER AND DIVISION 1/

Region/Division	Quantity 1st qtr. (thousand metric tons)	Percentage change 2/	Quantity 2d qtr. (thousand metric tons)	Percentage change 2/	Quantity 3d qtr. (thousand metric tons)	Percentage change 2/	Quantity 4th qtr. (thousand metric tons)	Percentage change 2/	Total 3/ (thousand metric tons)	Value total 3/ (thousands)
Northeast:										
New England	4,800	4.8	11,400	7.4	14,500	9.1	10,700	15.7	41,400	232,000
Middle Atlantic	6,900	-10.7	15,900	-12.6	19,200	-2.7	14,700	14.5	56,600	305,000
Midwest:										
East North Central	18,300	-9.7	53,900	-1.2	71,300	7.8	54,200	6.2	198,000	745,000
West North Central	11,200	4.5	31,200	25.4	40,600	7.3	24,900	6.0	108,000	347,000
South:										
South Atlantic	14,400	-0.6	19,800	5.9	20,100	13.0	17,800	5.1	72,100	313,000
East South Central	7,700	7.0	12,900	18.8	13,100	4.5	10,500	6.0	44,100	185,000
West South Central	22,900	19.3	27,600	17.9	24,800	-1.6	22,500	-6.1	97,800	432,000
West:										
Mountain	33,300	3.3	44,300	8.4	44,300	3.0	39,800	-2.0	162,000	710,000
Pacific 4/	29,800	13.6	45,700	11.5	52,100	12.8	41,700	2.0	169,000	862,000
Total 3/	149,300	4.7	262,700	8.1	300,000	6.5	236,800	3.5	963,000 5/	4,190,000

1/ As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 1996" Mineral Industry Survey.
2/ All percentage changes are calculated by using unrounded totals; percentage changes are based on the corresponding quarter of the previous year.
3/ Data may not add to toals shown because of independent rounding, and differences between projected totals by States and regions.
4/ Does not include Alaska and Hawaii.
5/ Includes Alaska.

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TABLE 4
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY
PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995			1996		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	12,000 r/	$49,700 r/	$4.16 r/	13,800	$60,600	$4.40
Alaska 2/	8,920 r/	33,800 r/	3.80 r/	9,380	35,900	3.83
Arizona	40,100	201,000	5.00	41,900	199,000	4.75
Arkansas	11,600	48,300	4.18	11,000	43,500	3.97
California	98,400	542,000	5.51	103,000	583,000	5.65
Colorado	35,000 r/	144,000 r/	4.11 r/	31,600	133,000	4.19
Connecticut	6,410	37,500	5.85	6,380	26,900	4.21
Delaware	2,680	8,740	3.26	2,370	6,820	2.88
Florida	19,300	69,300	3.58	18,500	68,800	3.72
Georgia	5,780	23,100	4.00	6,520	24,500	3.75
Hawaii	405	4,030	9.95	W	W	W
Idaho	13,200	43,500	3.30	14,700	46,100	3.14
Illinois	36,100	147,000	4.07	34,600	144,000	4.17
Indiana	24,900	93,900	3.78	24,800	100,000	4.03
Iowa	14,300	57,000	4.00	13,300	54,600	4.11
Kansas	11,100	29,400	2.65	11,500	31,300	2.72
Kentucky	8,710	31,700	3.63	7,310	25,600	3.50
Louisiana	11,300	50,200	4.43	11,500	53,200	4.62
Maine	6,420	26,900	4.18	6,440	27,500	4.27
Maryland	9,700	61,700	6.36	9,700	61,400	6.33
Massachusetts	11,700	67,500	5.76	14,200	82,500	5.79
Michigan	53,500	178,000	3.34	53,800	197,000	3.66
Minnesota	31,900	99,400	3.11	31,800	107,000	3.36
Mississippi	11,800	53,000	4.51	13,400	60,600	4.54
Missouri	8,840	32,400	3.66	9,820	35,600	3.62
Montana	8,870	34,900	3.93	9,260	35,800	3.87
Nebraska	13,700	47,100	3.43	12,900	44,300	3.44
Nevada	22,500	110,000	4.87	22,400	113,000	5.02
New Hampshire	7,190	34,300	4.77	7,620	36,500	4.79
New Jersey	14,000	80,300	5.74	13,200	70,400	5.33
New Mexico	10,400	50,700	4.88	9,880	48,500	4.91
New York	27,300	134,000	4.92	28,100	145,000	5.17
North Carolina	10,100	50,100	4.96	10,000	50,500	5.03
North Dakota	8,420	23,900	2.83	8,320	23,800	2.86
Ohio	45,300	196,000	4.33	46,600	215,000	4.60
Oklahoma	7,800	25,100	3.22	7,910	27,700	3.50
Oregon	18,200	85,000	4.66	18,300	86,800	4.75
Pennsylvania	17,100	93,100	5.44	15,100	85,600	5.68
Rhode Island	2,790	21,500	7.71	1,990	13,300	6.68
South Carolina	8,880	29,000	3.27	8,780	29,000	3.31
South Dakota	8,730	26,200	3.00	8,750	27,700	3.16
Tennessee	8,020	36,700	4.58	8,380	35,300	4.21
Texas	61,100	271,000	4.43	61,300	278,000	4.53
Utah	23,800	80,200	3.38	24,700	80,500	3.26
Vermont	3,220	11,000	3.43	3,870	15,200	3.93
Virginia	9,710	42,300	4.36	9,780	45,800	4.68
Washington	37,700	155,000	4.10	37,900	162,000	4.27
West Virginia	1,800	7,650	4.25	1,730	7,710	4.44
Wisconsin	32,200	102,000	3.16	32,600	105,000	3.23
Wyoming	3,860	17,500	4.55	3,420	14,700	4.28
Total	907,000 r/	3,900,000 r/	4.30 r/	914,000	4,000,000	4.38

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 5
SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY QUARTER AND STATE 1/

State	Quantity 1st qtr. (thousand metric tons)	Percentage change 2/	Quantity 2d qtr. (thousand metric tons)	Percentage change 2/	Quantity 3d qtr. (thousand metric tons)	Percentage change 2/	Quantity 4th qtr. (thousand metric tons)	Percentage change 2/	Total 3/ (thousand metric tons)	Value total 3/ (thousands)
Alabama	3,100	28.3	4,000	31.8	3,800	15.7	3,400	10.6	14,400	60,500
Alaska 4/	--	--	--	--	--	--	--	--	13,900	50,000
Arizona	9,800	6.8	11,100	4.4	10,400	2.8	9,700	-4.0	41,100	207,000
Arkansas	2,500	9.0	2,900	2.4	2,900	-14.8	2,400	-20.4	10,700	45,100
California	18,900	18.6	29,500	11.8	33,000	14.0	27,100	-0.3	108,000	602,000
Colorado	5,400	8.7	10,600	31.8	11,500	-0.5	8,600	-9.7	36,100	150,000
Connecticut	800	-19.9	2,200	13.3	2,600	25.9	1,800	25.6	7,380	43,600
Delaware	500	-20.0	1,100	52.1	1,100	82.9	900	34.6	3,660	12,100
Florida	4,800	(5/)	5,400	8.8	5,100	9.2	4,900	1.1	20,200	72,800
Georgia	1,400	7.2	1,900	18.5	1,800	14.7	1,600	18.0	6,630	26,900
Hawaii 4/	--	--	--	--	--	--	--	--	400	4,000
Idaho	1,400	-10.1	3,600	-28.3	4,500	21.8	5,100	73.7	14,600	48,900
Illinois	3,300	-12.7	10,500	-2.5	12,300	1.3	9,900	4.6	36,000	147,000
Indiana	2,900	-12.7	7,400	8.2	9,700	14.1	6,500	1.9	26,400	100,000
Iowa	1,100	-9.7	4,500	14.9	6,400	12.9	2,800	-17.3	14,900	60,400
Kansas	2,000	60.5	5,500	73.2	4,200	0.4	3,200	30.9	15,000	40,400
Kentucky	1,000	8.4	2,000	-13.9	2,200	-37.3	1,800	-8.5	7,010	25,700
Louisiana	2,800	8.9	3,300	0.2	2,900	0.7	2,800	6.6	11,700	52,200
Maine	700	20.2	2,000	-5.4	2,600	27.0	1,600	-10.1	6,790	28,500
Maryland	1,700	2.1	2,600	-9.7	3,300	18.9	2,600	10.2	10,200	65,400
Massachusetts	2,200	73.3	3,900	10.2	4,900	11.0	4,100	63.2	15,000	87,200
Michigan	4,200	-3.2	13,900	-11.1	21,200	13.4	15,400	3.6	54,700	186,000
Minnesota	3,600	9.9	8,400	-0.4	12,500	1.9	8,600	7.7	33,000	104,000
Mississippi	2,200	0.3	3,800	22.4	4,000	11.8	3,000	3.1	13,000	59,300
Missouri	1,400	-3.2	3,100	91.6	3,600	10.6	2,500	-0.3	10,600	39,200
Montana 6/	--	--	--	--	--	--	--	--	8,210	32,800
Nebraska	900	-32.4	3,800	0.2	6,300	10.5	3,400	13.7	14,300	49,300
Nevada	5,500	6.9	5,400	-7.6	4,900	-12.9	5,200	-10.2	21,100	103,000
New Hampshire	600	-39.7	1,600	-4.6	2,300	-10.6	1,700	-15.4	6,130	29,400
New Jersey	1,700	-34.5	3,900	-8.2	3,200	-20.5	4,000	25.5	12,700	73,900
New Mexico	2,600	9.5	2,900	1.7	2,800	3.9	2,700	8.2	11,000	53,800
New York	3,300	3.9	8,300	-5.7	10,800	14.6	7,300	24.1	29,700	147,000
North Carolina	2,000	-3.4	2,800	9.7	2,900	29.5	2,700	-18.0	10,300	51,600
North Dakota 6/	--	--	--	--	--	--	--	--	8,500	24,200
Ohio	4,700	-10.6	12,700	3.8	16,400	3.2	13,400	11.6	47,100	205,000
Oklahoma	1,700	10.6	2,400	24.5	2,100	-10.2	1,900	-3.1	8,140	26,400
Oregon	2,800	-3.2	4,600	4.3	6,300	-4.9	5,300	24.4	19,000	89,300
Pennsylvania	1,900	-2.4	4,200	-21.3	5,600	-9.3	3,700	-0.2	15,300	84,400
Rhode Island 6/	--	--	--	--	--	--	--	--	3,000	23,300
South Carolina	2,100	8.3	2,900	5.1	2,700	8.5	2,300	31.6	9,950	32,800
South Dakota	500	-34.1	2,600	6.5	4,500	20.5	2,000	8.7	9,530	29,100
Tennessee	1,000	-24.8	2,700	16.1	2,900	14.3	2,100	14.7	8,680	39,900
Texas	16,600	28.5	19,700	30.4	17,300	4.8	15,700	-5.2	69,300	308,000
Utah	3,200	-39.8	8,700	76.7	10,600	55.4	7,800	13.7	30,200	103,000
Vermont	600	52.4	1,700	125.4	2,000	57.0	1,500	82.6	5,770	19,900
Virginia	1,900	-4.9	2,900	5.0	2,900	8.4	2,600	10.2	10,200	44,900
Washington	8,000	2.7	11,200	12.4	13,000	15.7	9,100	4.7	41,300	171,000
West Virginia	200	-10.2	500	-8.5	500	-10.1	400	-15.9	1,600	6,890
Wisconsin	3,200	-10.0	9,500	2.9	11,600	5.1	9,300	9.9	33,500	107,000
Wyoming	500	-45.0	900	-24.0	500	-45.4	600	-35.4	2,450	11,300
Total	XX	XX	XX	XX	XX	XX	XX	XX	963,000	4,190,000

XX Not applicable.
1/As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 1996" Mineral Industry Survey.
2/All percentage changes are calculated by using unrounded totals; percentage changes are based on the corresponding quarter of the previous year.
3/Data may not add to toals shown because of independent rounding and differences between projected totals by States and regions.
4/ State not included in quarterly survey.
5/Less than 1/2 unit.
6/ Owing to a low number of reporting companies, no production estimates by quarters were generated.

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TABLE 6
CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES IN 1996, BY MAJOR USE 1/

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Concrete aggregates (including concrete sand)	232,000	$1,130,000	$4.89
Plaster and gunite sands	7,450	39,600	5.31
Concrete products (blocks, bricks, pipe, decorative, etc.)	9,770	51,200	5.23
Asphaltic concrete aggregates and other bituminous mixtures	70,800	353,000	4.98
Road base and coverings	119,000	463,000	3.88
Road stabilization:			
Cement	4,700	16,700	3.54
Lime	1,760	9,480	5.37
Fill	63,900	186,000	2.91
Snow and ice control	6,800	27,700	4.07
Railroad ballast	974	4,800	4.93
Roofing granules	515	2,970	5.77
Filtration	1,120	6,230	5.54
Other miscellaneous uses	18,000	97,600	5.41
Unspecified: 2/			
Actual	174,000	776,000	4.46
Estimated	203,000	836,000	4.12
Total	914,000	4,000,000	4.38

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes production reported without a breakdown by end use and estimates for nonrespondents.

TABLE 7
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY GEOGRAPHIC DIVISION AND MAJOR USE 1/

(Thousand metric tons and thousand dollars)

Region/Division	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures		Road base and coverings 2/	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	6,250	$37,700	105	1,010	140	$930	2,280	$13,800	5,890	$26,600
Middle Atlantic	15,200	96,300	515	3,480	715	5,180	6,910	35,200	7,740	36,100
Midwest:										
East North Central	39,800	162,000	671	2,960	3,050	14,900	13,300	55,800	24,300	95,300
West North Central	19,400	80,000	384	1,940	648	4,100	6,850	25,400	20,800	51,800
South:										
South Atlantic	22,400	96,500	1,440	5,370	2,190	9,290	2,220	9,120	2,510	13,900
East South Central	9,950	43,900	329	2,460	620	3,730	3,540	15,900	3,480	12,300
West South Central	34,800	169,000	292	1,670	477	1,350	3,130	16,000	4,170	14,500
West:										
Mountain	32,600	164,000	1,690	7,150	1,090	5,200	15,400	77,400	35,600	135,000
Pacific	51,800	285,000	2,030	13,500	848	6,460	17,200	104,000	21,400	103,000
Total	232,000	1,130,000	7,450	39,600	9,770	51,200	70,800	353,000	126,000	489,000

Region/Division	Fill		Snow and ice control		Railroad ballast		Other uses		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	4,110	$13,900	2,430	$9,030	181	$994	19,200	$97,900	40,500	$202,000
Middle Atlantic	4,260	12,400	1,820	7,840	35	217	19,200	105,000	56,400	301,000
Midwest:										
East North Central	15,700	54,200	1,110	3,780	44	278	94,400	371,000	192,000	761,000
West North Central	5,050	10,100	571	2,010	316	819	42,400	148,000	96,500	324,000
South:										
South Atlantic	7,110	19,600	81	409	123	882	29,400	140,000	67,400	295,000
East South Central	951	3,090	W	W	W	W	23,900	101,000	42,800	182,000
West South Central	6,360	13,200	W	W	W	W	42,500	186,000	91,700	402,000
West:										
Mountain	10,200	26,000	447	2,880	61	306	60,800	252,000	158,000	670,000
Pacific	10,200	33,800	294	1,480	211	1,300	64,600	318,000	169,000	867,000
Total	63,900	186,000	6,800	27,700	974	4,800	396,000	1,720,000	914,000	4,000,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes road and other stabilization (cement and lime).

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TABLE 8
CONSTRUCTION SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 1996,
BY REGION AND SIZE OF OPERATION 1/

Size range (metric tons)	Northeast				Midwest				South			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	378	37.4	3,060	3.2	523	25.7	5,270	1.8	207	20.3	1,880	0.9
25,000 to 49,999	162	16.0	5,220	5.4	310	15.2	10,200	3.5	126	12.4	4,250	2.1
50,000 to 99,999	166	16.4	11,000	11.3	397	19.5	25,900	9.0	175	17.2	11,200	5.5
100,000 to 199,999	140	13.8	17,800	18.4	319	15.7	41,000	14.2	177	17.4	22,900	11.3
200,000 to 299,999	87	8.6	19,100	19.7	180	8.8	39,300	13.6	106	10.4	23,300	11.6
300,000 to 399,999	28	2.8	8,860	9.1	94	4.6	29,300	10.2	66	6.5	20,000	9.9
400,000 to 499,999	18	1.8	7,330	7.6	57	2.8	22,900	7.9	34	3.3	14,000	7.0
500,000 to 599,999	9	.9	4,590	4.7	52	2.6	25,700	8.9	34	3.3	17,100	8.4
600,000 to 699,999	8	.8	4,520	4.7	31	1.5	18,100	6.3	23	2.3	13,400	6.6
700,000 to 799,999	4	.4	2,750	2.8	23	1.1	15,600	5.4	14	1.4	9,430	4.7
800,000 to 899,999	2	.2	1,540	1.6	16	.8	12,400	4.3	11	1.1	8,330	4.1
900,000 to 999,999	1	.1	898	.9	5	.2	4,290	1.5	10	1.0	8,590	4.3
1,000,000 to 1,499,999	7	.7	7,360	7.6	16	.8	17,400	6.0	28	2.7	30,500	15.1
1,500,000 to 1,999,999	–	–	–	–	9	.4	13,300	4.6	4	.4	6,290	3.1
2,000,000 to 2,499,999	–	–	--	–	3	.1	5,760	2.0	4	.4	8,030	4.0
2,500,000 to 4,999,999	1	.1	2,900	3.0	1	(2/)	2,370	.8	1	.1	2,700	1.3
5,000,000 and more	–	–	–	–	–	–	–	–	–	–	–	–
Total	1,011	97	96,900	100	2,036	100	289,000	100	1,020	100	202,000	100

Size range (metric tons)	West				U.S. total			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	364	24.3	3,460	1.1	1,472	26.5	13,700	1.5
25,000 to 49,999	184	12.3	5,920	1.8	782	14.1	25,600	2.8
50,000 to 99,999	260	17.4	16,900	5.2	998	17.9	64,900	7.1
100,000 to 199,999	230	15.4	29,900	9.2	866	15.6	112,000	12.3
200,000 to 299,999	114	7.6	25,000	7.7	487	8.8	107,000	11.7
300,000 to 399,999	78	5.2	24,400	7.5	266	4.8	82,600	9.0
400,000 to 499,999	60	4.0	24,400	7.5	169	3.0	68,700	7.5
500,000 to 599,999	45	3.0	22,200	6.8	140	2.5	69,600	7.6
600,000 to 699,999	27	1.8	15,700	4.8	89	1.6	51,700	5.7
700,000 to 799,999	26	1.7	17,500	5.4	67	1.2	45,400	5.0
800,000 to 899,999	20	1.3	15,200	4.7	49	.9	37,400	4.1
900,000 to 999,999	10	.7	8,600	2.6	26	.5	22,400	2.5
1,000,000 to 1,499,999	47	3.1	50,900	15.6	98	1.8	106,000	11.6
1,500,000 to 1,999,999	16	1.1	24,600	7.5	29	.5	44,200	4.8
2,000,000 to 2,499,999	7	.5	14,000	4.3	14	.3	27,800	3.0
2,500,000 to 4,999,999	6	.4	20,600	6.3	9	.2	28,600	3.1
5,000,000 and more	1	.1	7,100	2.2	1	(2/)	7,100	0.8
Total	1,495	98.4	326,000	100	5,562	98	914,000	100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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TABLE 9
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1996, BY GEOGRAPHIC DIVISION

Region/Division	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	186	156	38	37	1	418
Middle Atlantic	196	255	51	52	39	593
Midwest:						
East North Central	377	373	102	101	91	1,044
West North Central	226	427	42	71	226	996
South:						
South Atlantic	129	49	9	69	124	380
East South Central	116	23	10	14	64	227
West South Central	194	48	15	67	89	413
West:						
Mountain	286	441	100	39	18	884
Pacific 1/	293	179	69	38	32	611
Total	2,003	1,951	436	488	684	5,562

1/ An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.
2/ Hawaii excluded from all sand and gravel statistics.

TABLE 10
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1996, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Alabama	42	10	1	10	23	86
Alaska 1/	5	6	1	3	2	17
Arizona	54	53	28	2	2	139
Arkansas	34	7	4	7	7	59
California	164	67	40	14	17	302
Colorado	53	104	26	10	11	204
Connecticut	26	17	7	2	1	53
Delaware	1	3	--	2	3	9
Florida	16	4	--	4	35	59
Georgia	10	2	--	1	29	42
Idaho	32	73	4	6	1	116
Illinois	42	36	25	11	33	147
Indiana	58	29	17	7	21	132
Iowa	46	58	5	9	31	149
Kansas	15	33	7	16	47	118
Kentucky	11	1	3	--	8	23
Louisiana	18	4	2	3	38	65
Maine	32	59	3	13	--	107
Maryland	21	3	6	14	3	47
Massachusetts	65	15	9	7	--	96
Michigan	95	131	25	43	13	307
Minnesota	74	153	19	19	1	266
Mississippi	34	4	6	4	23	71
Missouri	33	12	1	1	35	82
Montana	41	60	3	6	--	110
Nebraska	24	21	--	5	112	162
Nevada	22	29	10	9	--	70
New Hampshire	21	21	8	3	--	53
New Jersey	23	3	7	4	14	51
New Mexico	32	40	13	2	--	87
New York	110	227	31	41	9	418
North Carolina	26	20	--	30	25	101
North Dakota	13	61	4	1	--	79
Ohio	108	17	22	29	21	197

See footnote at end of table.

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TABLE 10--Continued
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1996, BY STATE

State	Mining operations on land					
	Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Oklahoma	15	7	1	17	26	66
Oregon	46	28	6	4	4	88
Pennsylvania	63	25	13	7	16	124
Rhode Island	11	--	3	--	--	14
South Carolina	21	5	2	9	15	52
South Dakota	21	89	6	20	--	136
Tennessee	29	8	--	--	10	47
Texas	127	30	8	40	18	223
Utah	41	54	11	2	1	109
Vermont	31	44	8	12	--	95
Virginia	20	12	1	9	13	55
Washington	78	78	22	17	9	204
West Virginia	14	--	--	--	1	15
Wisconsin	74	160	13	11	3	261
Wyoming	11	28	5	2	3	49
Total	2,003	1,951	436	488	684	5,562

1/ An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

TABLE 11
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY REGION AND METHOD OF TRANSPORTATION 1/

(Thousand metric tons)

Region/Division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	17,800	578	--	49	3,620	18,500	40,500
Middle Atlantic	28,900	--	1,550	143	5,360	20,400	56,400
Midwest:							
East North Central	78,400	492	3,200	716	15,100	94,500	192,000
West North Central	38,000	402	4,000	1,010	7,610	45,500	96,500
South:							
South Atlantic	32,300	1,350	193	7	3,960	29,600	67,400
East South Central	14,700	7	1,540	56	2,220	24,300	42,800
West South Central	36,800	5,030	2,020	173	6,140	41,500	91,700
West:							
Mountain	79,600	302	--	207	16,600	61,200	158,000
Pacific 2/	73,400	1,270	4,770	812	22,100	66,200	169,000
Total	400,000	9,440	17,300	3,170	82,700	402,000	914,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Hawaii excluded from all sand and gravel statistics.

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TABLE 12
U.S. EXPORTS OF CONSTRUCTION SAND AND GRAVEL IN 1996, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country or Territory	Sand		Gravel	
	Quantity	F.a.s. value 2/	Quantity	F.a.s. value 2/
North America:				
Bahamas, The	1	144	(3/)	8
British Virgin Islands	--	--	3	36
Canada	251	3,610	312	1,690
Mexico	678	5,540	18	2,090
Netherlands Antilles	(3/)	28	23	489
Trinidad and Tobago	3	157	--	--
Other 4/	3	433	2	63
Total	933	9,910	358	4,380
South America:				
Argentina	5	1,060	1	181
Ecuador	85	1,270	(3/)	5
Peru	4	490	--	--
Venezuela	41	1,510	--	--
Other 5/	4	729	3	268
Total	138	5,060	4	454
Europe:				
Belgium	6	157	--	--
Germany	5	215	3	91
Spain	1	18	--	--
Sweden	(3/)	120	--	--
United Kingdom	15	78	1	89
Other 6/	3	247	(3/)	7
Total	31	834	3	187
Asia:				
Hong Kong	1	33	(3/)	5
Japan	12	401	1	31
Korea, Republic of	2	134	1	42
Philippines	1	14	--	--
Singapore	1	147	--	--
Taiwan	(3/)	61	1	50
Thailand	2	155	--	--
Other 7/	2	884	1	7
Total	20	1,830	3	134
Oceania, other 8/	2	96	(3/)	4
Middle East, other 9/	1	228	(3/)	9
Africa:				
Equatorial Guinea	23	75	--	--
South Africa, Republic of	12	9	--	--
Other 10/	1	101	--	--
Total	36	185	--	--
Grand total	1,160	18,100	368	5,160

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ F.a.s. (free alongside ship) value of material at U.S. port of export; based on transaction price including all charges incurred in placing material alongside ship.

3/ Less than 1/2 unit.

4/ Includes Aruba, Barbados, Bermuda, Cayman Islands, the Dominican Republic, El Salvador, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Panama, Saint Kitts and Nevis, and Saint Lucia.

5/ Includes Bolivia, Brazil, Chile, Colombia, and Uruguay.

6/ Includes Denmark, France, Ireland, Italy, Netherlands, Norway, Romania, and Switzerland.

7/ Includes China, India, Indonesia, Malaysia, and Pakistan.

8/ Includes Australia and New Zealand.

9/ Includes Israel, Kuwait, Saudi Arabia, the United Arab Emirates, and Yemen.

10/ Includes Algeria and Nigeria.

Source: Bureau of the Census.

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TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF CONSTRUCTION SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country or Territory	1995 Quantity	1995 C.i.f. value 2/	1996 Quantity	1996 C.i.f. value 2/
Australia	14 r/	1,350	7	1,080
Bahamas, The	189 r/	438	159	410
British Virgin Islands	4	69	1	8
Canada	786 r/	5,590	965	8,100
Dominica	17 r/	242	22	284
France	1	258	1	326
Germany	2 r/	664	(3/)	292
Japan	7 r/	792	2	534
Martinique	21 r/	212	--	--
Mexico	68 r/	651	51	1,260
Netherlands Antilles	(3/)	2	32	401
United Kingdom	1	668	3	882
Other 4/	5 r/	1,020 r/	22	2,250
Total	1,120	12,000	1,260	15,800

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ C.i.f. (cost, insuance, freight) value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

3/ Less than 1/2 unit.

4/ Includes Antigua and Barbuda (1996), Bosnia-Herzegovina (1996), China, the Dominican Republic, India, Macao (1995), Namibia (1996), New Zealand, Singapore (1995), and Venezuela.

Source: Bureau of the Census.

TABLE 14
RECYCLED ASPHALT AND CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY REGION 1/

Region/Division	Recycled asphalt 1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	Recycled asphalt 1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value	Recycled concrete 1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	Recycled concrete 1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value
Northeast:												
New England	193	$739	3.83	276	$1,020	3.69	212	$768	3.62	165	$794	4.81
Middle Atlantic	W	W	3.60	21	129	6.14	351	1,520	4.34	362	2,370	6.54
Midwest:												
East North Central	401	1,360	3.38	549	1,750	3.19	592	2,390	4.04	425	1,920	4.52
West North Central	582	1,860	3.20	394	1,260	3.19	1,290	2,790	2.16	1,180	3,140	2.65
South:												
South Atlantic	347	1,850	5.32	542	2,210	4.08	261	1,180	4.51	179	734	4.10
East South Central	224	966	4.31	291	889	3.05	--	--	--	--	--	--
West South Central	W	W	7.36	16	49	3.06	3	15	5.00	28	42	1.50
West:												
Mountain	1,150	5,950	5.17	463	2,010	4.35	383	1,470	3.84	419	1,570	3.76
Pacific 2/	563	3,010	5.35	1,190	4,980	3.85	501	2,120	4.23	1,270	4,530	3.58
Total	3,510	16,000	4.56	3,740	14,300	3.82	3,600	12,300	3.41	4,030	15,100	3.75

W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes Hawaii.

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TABLE 15
RECYCLED ASPHALT SOLD OR USED BY SAND AND GRAVEL PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995			1996		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	41	$262	$6.39	12	$50	$4.17
Alaska	W	W	5.90	W	W	4.35
Arizona	W	W	5.67	80	592	7.40
California	357	1,450	4.06	678	3,040	4.49
Colorado	135	628	4.65	43	174	4.05
Connecticut	24	39	1.63	W	W	7.60
Florida	2	14	7.00	--	--	--
Idaho	163	319	1.96	W	W	1.87
Illinois	W	W	7.50	127	214	1.69
Indiana	--	--	--	28	217	7.75
Iowa	10	33	3.30	10	50	5.00
Kansas	W	W	3.26	72	255	3.54
Louisiana	--	--	--	5	36	7.20
Maine	80	402	5.03	125	608	4.86
Maryland	W	W	3.84	--	--	--
Massachusetts	61	210	3.44	122	280	2.30
Michigan	242	919	3.80	141	584	4.14
Minnesota	487	1,470	3.01	297	868	2.92
Mississippi	177	680	3.84	177	525	2.97
Montana	57	240	4.21	132	425	3.22
Nebraska	--	--	--	5	25	5.00
Nevada	W	W	10.48	--	--	--
New Hampshire	25	76	3.04	21	79	3.76
New Jersey	W	W	3.60	10	46	4.60
New Mexico	200	827	4.14	87	422	4.85
New York	--	--	--	10	72	7.20
North Carolina	238	1,420	5.98	318	1,290	4.05
North Dakota	W	W	5.83	W	W	5.33
Ohio	W	W	1.10	15	82	5.47
Oregon	38	290	7.63	35	399	11.40
Pennsylvania	--	--	--	W	W	6.00
Rhode Island	2	5	2.50	--	--	--
South Carolina	W	W	3.85	224	924	4.13
South Dakota	60	266	4.43	W	W	6.00
Tennessee	5	24	4.80	103	314	3.05
Texas	22	W	W	W	W	1.08
Utah	143	396	2.77	W	W	3.50
Vermont	2	7	3.50	3	13	4.33
Washington	116	965	8.32	381	1,130	2.96
Wisconsin	119	380	3.19	239	656	2.74
Wyoming	W	W	6.62	35	234	6.69
Total	3,510	16,000	4.56	3,740	14,300	3.82

W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 16
RECYCLED CONCRETE SOLD OR USED BY SAND AND GRAVEL PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995			1996		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alaska	6	$41	$6.83	--	--	--
Arizona	--	--	--	9	$10	$1.11
California	434	1,790	4.13	1,040	3,710	3.57
Colorado	80	381	4.76	57	273	4.79
Connecticut	68	110	1.62	--	--	--
Idaho	W	W	3.33	W	W	3.00
Illinois	70	489	6.99	124	552	4.45
Indiana	W	W	3.33	W	W	4.04
Iowa	5	26	5.20	69	405	5.87
Kansas	1	2	2.00	2	5	2.50
Maine	--	--	--	11	58	5.27
Maryland	W	W	3.40	92	203	2.21
Massachusetts	132	594	4.50	153	736	4.81
Michigan	361	1,210	3.36	106	513	4.84
Minnesota	1,170	2,320	1.97	1,120	2,730	2.44
Montana	W	W	3.19	W	W	4.61
Nevada	W	W	3.23	W	W	3.32
New Hampshire	W	W	5.60	W	W	2.45
New Jersey	W	W	3.31	W	W	4.00
New Mexico	21	61	2.90	88	393	4.47
New York	234	1,130	4.84	360	2,350	6.54
North Carolina	W	W	7.19	W	W	5.60
North Dakota	W	W	4.00	--	--	--
Ohio	W	W	5.69	W	W	7.73
Oregon	W	W	2.00	65	271	4.17
Pennsylvania	W	W	5.52	W	W	5.50
Rhode Island	2	5	2.50	--	--	--
South Carolina	W	W	8.91	W	W	6.67
South Dakota	111	433	3.90	--	--	--
Texas	W	W	5.00	28	42	1.50
Utah	5	15	3.00	W	W	2.05
Vermont	5	30	6.00	--	--	--
Washington	61	283	4.64	160	547	3.42
Wisconsin	45	117	2.60	59	185	3.14
Wyoming	24	189	7.88	W	W	6.67
Total 2/	3,600	12,300	3.41	4,030	15,100	3.75

W Withheld to avoid disclosing company proprietary data; included in "Total."

1/ Excludes Hawaii.

2/ Data are rounded to three significant digits; may not add to totals shown.

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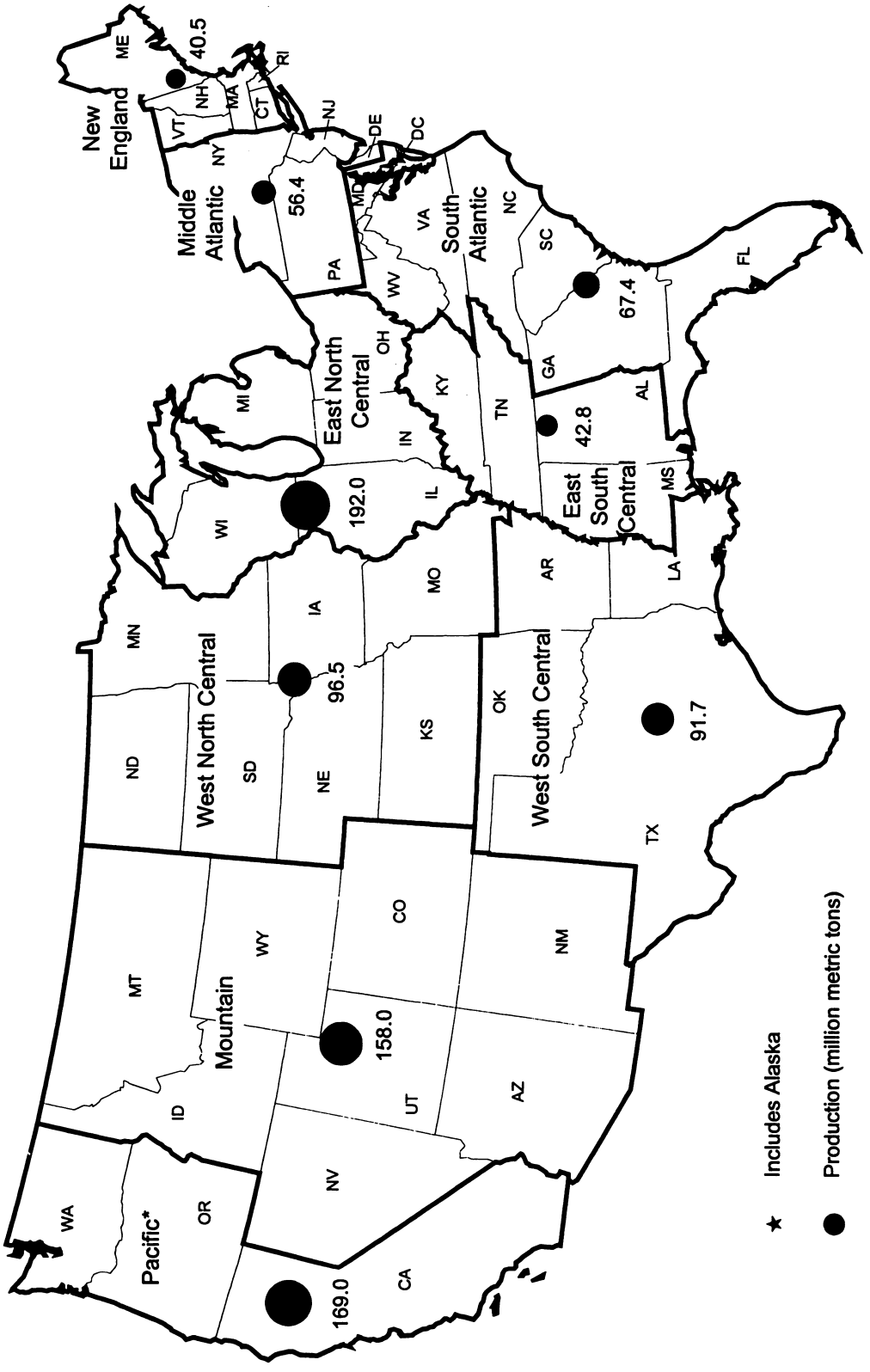
FIGURE 1
PRODUCTION OF CONSTRUCTION SAND AND GRAVEL IN THE UNITED STATES IN 1996, BY GEOGRAPHIC DIVISION



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SELENIUM AND TELLURIUM

By Robert D. Brown, Jr.

Primary selenium was produced domestically as a byproduct of copper refining in 1996; there was no production of secondary (recycled) selenium. Five electrolytic copper refineries generated selenium-containing anode slimes. Two of the refineries recovered commercial grade selenium, one recovered a semirefined filter cake, which it shipped to Asia for further refining, and two exported anode slimes for refining. Domestic production, excluding exported anode slimes, increased in 1996 to a level slightly higher than the previous high, obtained in 1995.

Domestic apparent consumption of selenium increased a small amount to a level higher than the recent apex, reached in 1994, but not as high as the levels of 1988 and 1989. Selenium use as a photoreceptor for plain paper copiers has been decreasing each year recently in favor of cheaper organic compounds. Otherwise, the distribution among end-use sectors remained nearly the same. Estimates of end-use demand in 1996 are as follows: glass, 25%; photoreceptors, 16%; metallurgical applications, 16%; miscellaneous chemical uses, 15%; pigments, 8%; and other uses, including agricultural feed additives, 20%.

All selenium-containing scrap generated was exported for reprocessing. Worldwide, about 250 metric tons of secondary selenium is produced annually. World refinery production of selenium increased 4%, to 2,150 metric tons; Japan, Canada, the United States, Belgium, and Germany were the largest producers in order of output. World production was slightly lower than the level achieved in 1994.

Tellurium was recovered by one company from anode slimes generated in the electrolytic refining of copper and from soda slag skimmings generated in lead refining. There was no domestic production of secondary tellurium, but some scrap was exported for recycling. Production data are company proprietary. Domestic consumption was believed to have increased in 1996. About 55% of the tellurium was used as free-machining additives to steel. Other uses included catalysts, chemical uses, nonferrous alloys, photoreceptors, and thermoelectric devices.

Domestic Data Coverage

Domestic data are collected by a voluntary survey of the domestic producers of selenium and tellurium. The selenium production canvass was sent to the three known producers and tellurium to the sole producer. All companies responded, but company proprietary data are not released.

Legislation and Government Programs

Tellurium metal was removed from the Environmental Protection Agency's (EPA's) most hazardous list. Its placement on the list had been based on the properties of a tellurium compound that is quite soluble in water and was already on the list. When informed that the properties of tellurium metal are quite different, EPA removed tellurium metal from the list (Federal Register, 1996).

Production

Selenium was recovered from anode slimes generated in the electrolytic production of copper. Domestic production increased slightly to a new high. Three domestic copper refineries recover selenium: ASARCO Incorporated, Amarillo, TX; Phelps Dodge Refining Corp., El Paso, TX; and Kennecott Utah Copper Corp., Magna, UT. One producer exported semirefined selenium (90% selenium content) for toll-refining in Asia. Two other companies generated selenium-containing slimes, but did not produce selenium. Selenium-containing slimes from the other two refineries were exported for processing.

Most domestic selenium was produced as commercial-grade metal, averaging a minimum of 99.5% selenium and available in various forms, including shot, lump, or powder, or as pigment-grade powder having a minimum 99.8% selenium content.

Commercial grade tellurium and tellurium dioxide were produced by Asarco at Amarillo, TX, mainly from copper anode slime, but also from lead refinery skimmings. Asarco also produced high purity tellurium (99.999% purity) and selenium (99.999% purity) and other high purity metals and compounds at its plant in Denver, CO. Detector-grade tellurium (99.99999% purity) was produced by Cabot Performance Metals, Revere, PA.

Consumption

Selenium demand by end use can be divided broadly into six categories: glass manufacturing, electronics (including photoreceptor uses), agricultural and other uses, metallurgical applications, chemicals, and pigments. In glass manufacturing, selenium is used principally as a decolorant in container glass and other soda-lime silica glasses. The addition of selenium under weak oxidizing conditions adds a pink color to the glass that combines with the green color imparted by ferrous ions to create a neutral gray color that has low perceptibility to the

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human eye. Selenium is also used to reduce solar heat transmission in architectural plate glass and to add red color to glass, such as that used in traffic lights. Glass manufacturing accounted for about 25% of the selenium market in 1996.

In electronics, a large end-use market, accounting for 16% of selenium use, high-purity selenium compounds were used principally as photoreceptors on the drums of plain paper copiers. Photoreceptors have been the largest single application for selenium over the past decade. However selenium compounds are being replaced by organic photoreceptor compounds (OPC), which reportedly offer better performance and lower cost at printing speeds under 80 pages per minute and comparable cost and performance at faster printing speeds. OPC's also are free of the environmental concerns associated with the disposal of selenium compounds. Other electronic uses included rectifier and photoelectric applications.

Other uses, mainly agriculture, comprise about 20% of the market. Dietary supplements for livestock are the largest agricultural usage, although selenium also may be added to fertilizer, a practice that is more prevalent outside the United States.

Metallurgical uses comprised an estimated 16% of the market. Selenium is added to steel, copper, and lead alloys to improve machinability and casting and forming properties. Several domestic producers of rolled steel bar produce both leaded and selenium-bearing free-machining rod. However, selenium-containing free-cutting steels are generally cost competitive only when used with high-speed automatic machine tools. It is estimated that more than one-half of the metallurgical uses are for these applications. A smaller amount is used for batteries. A more detailed breakdown of this category is not available.

Selenium is added to low-antimony lead alloys used in the support grids of lead-acid storage batteries. The addition of 0.02% selenium by weight as a grain refiner improves the casting and mechanical properties of the alloy. The quantity of selenium consumed in this application has been greatly affected by technological changes in battery grid manufacture. The development of low-maintenance batteries in the early 1970's encouraged the use of low-antimony grid alloys requiring selenium. Since 1975, lead-calcium maintenance-free automotive batteries have captured a greater share of the automotive battery market, decreasing the demand for selenium in this application. But more recently, hybrid batteries, which employ low-antimony lead positive plates and lead-calcium negative plates, have been gaining in usage, again increasing the demand for selenium.

Chemical uses of selenium, including industrial and pharmaceutical applications, accounted for about 15% of usage. Small quantities of selenium also are used as human food supplements; selenium has been recognized as a nutrient essential for human health. The principal pharmaceutical use of selenium is in antidandruff hair shampoos. Miscellaneous industrial chemical uses include lubricants, rubber compounding, and catalysts.

In pigment applications, selenium was used to produce color changes in cadmium-sulfide-based pigments. With increasing substitution of selenium for sulfur, the yellow cadmium pigment becomes more red. Sulfoselenide red pigments have good heat stability and are used in ceramics and plastics, as well as in paints, inks, and enamels. Because of the relatively high cost and the toxicity of cadmium-based pigments, their use is generally restricted to applications requiring long life, brilliance, high thermal stability, and chemical resistance. Pigments were about 8% of the market.

Apparent domestic and world demand for tellurium increased in 1996. The largest use for tellurium was as an additive to free-machining steel, about 50% of the market. Chemicals and catalyst usage was about 25% of the market. Additives to nonferrous alloys used about 10%, and photoreceptor and thermoelectric applications accounted for another 10%. Other uses were about 5%.

Tellurium is used principally as an alloying element in the production of free-machining low-carbon steels, where additions of up to 0.1% tellurium, usually in conjunction with lead, greatly improve machinability. Similarly, the addition of tellurium to copper and other nonferrous alloys improves their machinability, strength, and corrosion resistance. Tellurium catalysts are used chiefly for the oxidation of organic compounds but are used also in hydrogenation, halogenation, and chlorination reactions. Tellurium chemicals are used as curing and accelerating agents in rubber compounding.

Electronic semiconductor applications for high-purity tellurium include its use with selenium as a photoreceptor in plain paper copiers and in thermoelectric and photoelectric devices. Mercury-cadmium-telluride is used as a sensing material for thermal imaging devices.

Thermoelectric cooling devices, based on bismuth-telluride semiconducting materials, are finding wider application in electronic and in some consumer applications. These devices consist of a series of couples of different semiconducting materials, which when connected to a direct current, cause one side of the thermoelement to cool while the other side evolves heat. The warm side is connected to a heat sink to dissipate the heat. Thermoelectric coolers are still used to cool infrared detectors, integrated circuits, medical instrumentation, and laser diodes more than for consumer products, such as portable coolers.

Prices

The domestic producer price for selenium averaged $4.00 per pound in 1996. The price drifted downward from just below $5.00 at the beginning of the year to just above $3.00 per pound at yearend. The producer price for tellurium fell to $21 per pound by yearend, averaging about $22 for the year.

World Review

World production and consumption data for selenium and tellurium were limited. Apparently, the supply is adequate to meet demand. Supply and demand have been in fairly close

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balance for several years. Better productivity has increased the modest oversupply, putting downward pressure on prices.

Current Research and Technology

In a study released early in 1996, the National Cancer Institute found that women having high blood levels of selenium were five times less likely to develop ovarian cancer than women with the lowest levels. While further testing to verify this effect is indicated, researchers believe that 70 to 120 micrograms of selenium daily as a human dietary supplement is also indicated. This amount is well below the threshold amount for toxic effects (thought to be higher than 1,000 micrograms.) A steady daily dosage of 120 micrograms of selenium will increase the blood levels of selenium of a person living in a selenium-poor region of the United States to just below that obtained naturally without supplementation by persons living in selenium rich areas (Colditz, 1996). Researchers have also found that Brazil nuts with shells, from selenium-rich central Brazil, contain 120 micrograms of selenium per nut (Yeykal, 1996).

Late in the year, the Journal of the American Medical Association (JAMA) announced the results of a study thought at first to be a "failure"—because a hoped for reduction in the recurrence of skin cancer with selenium therapy was not obtained. But the data revealed significant reductions in the rate of occurrence for lung, prostate, colon, and rectal cancers. The subjects receiving selenium instead of a placebo received 200 micrograms per day. The study was conducted in a selenium-poor region of the country. These results, approaching the "too-good-to-be-true" level, caused much excitement; but the JAMA editors have concluded that "for now it is premature to change individual behavior, to market specific selenium supplements, or to modify public health recommendations based on the results of this one randomized trial" (Clark, 1996).

Outlook

Selenium supply is dependent upon copper production; and in the past several years, it has exceeded demand. Because it is recovered as a byproduct, selenium output cannot be easily adjusted to meet market conditions, resulting in supply and price fluctuations. Although several new uses have been developed, they have not yet impacted the overall demand for selenium. Demand for selenium in photoreceptors is likely to continue to decline as the cost of using organic compounds decreases. The largest possible increase in demand would come from use as an additive to plumbing brass, as part of the efforts to produce lead-free alloys for this sector.

Tellurium supply and demand have remained in close balance since 1990. This situation is likely to continue as there are no large increases foreseen in either consumption or production for the immediate future. Demand for high purity tellurium may increase for solar cells, and this could have a major impact on demand. Little information is available on the selenium or tellurium content of new ore bodies.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT SELENIUM AND TELLURIUM STATISTICS 1/

(Kilograms of contained metal unless otherwise specified)

	1992	1993	1994	1995	1996
Selenium:					
United States:					
Production, primary refined	243,000 2/	283,000 2/	360,000 2/	373,000 2/	379,000
Shipments to consumers	221,000	258,000	302,000	320,000	400,000
Exports, metal, waste and scrap	175,000	261,000	246,000	270,000 r/	322,000
Imports for consumption 3/	371,000	382,000	441,000	324,000	434,000
Apparent consumption, metal 4/	490,000	460,000	530,000	517,000	543,000
Dealers' price, average per pound, commercial grade 5/	$5.13	$4.90	$4.90	$4.89	$4.00
World: Refinery production	1,770,000	1,740,000 r/	2,160,000 r/	2,070,000	2,150,000
Tellurium:					
United States:					
Imports for consumption 6/	48,400	45,000	27,400	45,800	73,700
Producer price quote, yearend, commercial grade, per pound	$35.00	$32.00	$26.00	$23.00	$21.00

r/ Revised.
1/ Data are rounded to three significant digits.
2/ Includes semirefined selenium produced by one company and exported for refining.
3/ Includes unwrought and waste and scrap and selenium dioxide.
4/ Calculated using reported shipments, imports of selenium metal, and estimated exports of selenium metal, excluding scrap.
5/ Source: Metals Week. Calculated from published price ranges.
6/ Includes only unwrought and waste and scrap.

TABLE 2
U.S. EXPORTS OF SELENIUM METAL AND WASTE AND SCRAP 1/

(Kilograms, contained selenium)

	1995		1996	
	Quantity	Value	Quantity	Value
Argentina	--	--	3,430	$32,100
Australia	--	--	317	7,090
Austria	401	$6,200	--	--
Belgium	46,700	309,000	18,100	64,100
Brazil	14,600	220,000	23,700	368,000
Canada	1,090	29,900	1,140	31,300
China	--	--	13,200	205,000
Denmark	1,730	41,500	--	--
El Salvador	3,710	57,500	--	--
France	23,600	119,000	19,100	68,600
Germany	1,040	28,300	208	2,930
India	15,500	247,000	14,100	222,000
Israel	1,000	11,200	40	3,290
Japan	4,700	25,900	470	7,280
Korea, Republic of	4,620	80,300	7,980	123,000
Mexico	30,700	520,000	30,800	414,000
Netherlands	32,300	237,000	36,600	307,000
Philippines	80,900	253,000	147,000	738,000
Poland	182	2,910	--	--
South Africa	370	5,910	--	--
Syria	952	27,200	--	--
Taiwan	1,430	22,900	211	3,260
United Kingdom	332	2,690	311	4,820
Venezuela	4,050	43,000	3,090	31,400
Other	--	--	2,180	36,100
Total	270,000 r/	2,290,000 r/	322,000	2,670,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF SELENIUM 1/

(Kilograms, contained selenium)

Class and country	1995		1996	
	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:				
Australia	5,540	$44,600	--	--
Barbados	80	2,400	--	--
Belgium	45,900	1,980,000	55,300	$1,490,000
Canada	128,000	2,220,000	133,000	2,120,000
Chile	--	--	14,300	106,000
China	528	18,000	5,000	36,900
Finland	3,600	28,800	7,650	46,600
Germany	4,200	96,700	475	15,700
Korea, Republic of	--	--	248	17,000
Japan	32,800	993,000	32,800	836,000
Netherlands	--	--	14,800	124,000
Peru	--	--	5,000	28,200
Philippines	67,500	462,000	131,000	589,000
Russia	8,110	74,900	2,010	12,400
Spain	1,000	8,400	--	--
United Kingdom	13,600	110,000	9,690	72,200
Other	--	--	1,450	9,310
Total	311,000	6,050,000	412,000	5,500,000
Selenium dioxide: 2/				
France	53	1,730	--	--
Germany	4,320	59,800	10,800	136,000
Japan	816	22,500	2,190	26,400
Spain	710	8,260	--	--
United Kingdom	6,890	88,400	8,850	167,000
Total	12,800	181,000	21,800	330,000
Grand total	324,000	6,230,000	434,000	5,830,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Figure adjusted by the U.S. Geological Survey.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM 1/

(Kilograms, gross weight)

Class and country	1995		1996	
	Quantity	Value	Quantity	Value
Unwrought and waste and scrap:				
Belgium	4,550	$262,000	6,860	$303,000
Canada	9,410	659,000	14,300	885,000
China	604	82,100	916	69,200
France	200	5,730	301	12,200
Germany	1	1,270	100	2,430
Japan	6,850	546,000	5,880	501,000
Mexico	--	--	961	13,100
Philippines	6,800	240,000	24,600	848,000
Peru	1,060	29,500	987	27,300
Russia	71	5,250	--	--
Switzerland	135	10,900	--	--
United Kingdom	16,100	593,000	18,800	525,000
Total	45,800	2,430,000	73,700	3,190,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 5
SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms, contained selenium)

Country 3/	1992	1993	1994	1995	1996 e/
Belgium e/	250,000	250,000	250,000	250,000	250,000
Canada 4/	294,057	295,000 e/	566,000	553,000	561,000
Chile e/	50,000	49,500	45,000	46,000	46,000
Finland	30,040	30,400	29,690 r/	29,000 r/ e/	30,000
Germany e/	125,000	120,000	120,000	115,000	120,000
India 5/	9,628 r/	11,116 r/	11,582 r/	11,449 r/	11,500
Japan	572,998	540,943	614,134	547,731 r/	610,000
Mexico	400	--	--	--	--
Peru	14,396	17,100 r/	21,000 r/	21,000 r/ e/	21,000
Philippines e/ 6/	60,000	40,000	40,000	40,000	40,000
Serbia and Montenegro	57,800	27,677	30,000 e/	30,000 e/	30,000
Sweden e/	32,000 7/	50,000	50,000	30,000	30,000
United States 8/	243,000	283,000	360,000	373,000	379,000 7/
Zambia 9/	31,785	26,967	21,290 r/	20,000 r/	20,000
Zimbabwe	1,736	1,113	2,009	2,000 e/	2,000
Total	1,770,000	1,740,000	2,160,000	2,070,000	2,150,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper and/or refinery residues, but did not recover refined selenium from these materials indigenously were excluded to avoid double counting. Table includes data available through Apr. 9, 1997.

3/ In addition to the countries listed, Australia produced refined selenium, but output is not reported; available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

4/ Excludes selenium intermediates exported for refining.

5/ Data are for Indian fiscal year beginning Apr. 1 of year stated.

6/ Incomplete; data shown are for primary production at Philippine Associated Smelting and Refining Corp.

7/ Reported figure.

8/ Includes production of semirefined selenium exported for further refining.

9/ Data are for year beginning Apr. 1 of year stated. Gross weight, purity unknown.

TABLE 6
TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms, contained tellurium)

Country 3/	1992	1993	1994	1995	1996 e/
Canada 4/	21,776	24,000 e/	42,000	102,000 r/	62,000 p/
Japan	57,178	46,768	47,256	43,129 r/	39,300
Peru e/	18,631 5/	17,400 r/	28,000 r/	28,000 r/	28,000
United States	W	W	W	W	W

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Estimated data are rounded to three significant digits.

2/ Insofar as possible data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined tellurium are excluded to avoid double counting. Table is not totaled because of the exclusion of data from major world producers, notably the former U.S.S.R. and the United States. Table includes data available through Apr. 9, 1997.

3/ In addition to the countries listed, Australia, Belgium, Chile, Germany, the Philippines, and the former U.S.S.R. are known to produce refined tellurium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels.

4/ Excludes tellurium intermediates exported for refining.

5/ Reported figure.

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SILICA

By Wallace P. Bolen

Beginning with this report, the U.S. Geological Survey (USGS) will report industrial sand and gravel, tripoli, specialty silica stone, and quartz crystal in a report entitled "Silica." There are several reasons why this is being done. All of these commodities are essentially crystalline silicon dioxide (SiO_2) with variations mostly related to their crystal sizes and minor or trace impurities. Additionally, tripoli usage has increasingly been shifting from fine abrasive to filler and often competes with ground sand. (Tripoli had previously been covered by the USGS abrasive minerals specialist.) In this report, the four categories noted above will be reviewed in separate sections. Future reports will likely continue the refinement of the silica chapter in order to provide the most useful and meaningful data.

The sections on tripoli and special silica stone covers tripoli and other fine-grained, porous silica materials that have similar properties and end uses (e.g., rottenstone and novaculite). It does not include certain fine-grained or porous silica materials, such as pumice, covered in the Minerals Yearbook published by the USGS.

Industrial Sand and Gravel

Industrial sand and gravel production, exports, and imports decreased in 1996 compared with 1995. However, because of the decreased exports, the apparent consumption of about 26.4 million metric tons was essentially unchanged from 1995. Industrial sand and gravel, often termed "silica," "silica sand," and "quartz sand," includes high SiO_2 content sands and gravels. These sands are used in glassmaking, for foundry, abrasive, and hydraulic fracturing applications, and many other uses. The specifications for each use varies but silica resources for most markets are abundant. The leading producing States were Illinois, Michigan, California, New Jersey, and Wisconsin. In almost all cases, silica mining employs open pit mining methods with standard mining equipment. Sand and gravel mining, in the vast majority of cases, has little environmental impact except for temporarily disturbing the immediate environment while mining operations are active.

Production of industrial sand and gravel in 1996 decreased to 27.8 million metric tons, about 1.5% less than 1995's production. This decrease, although minor, represents the first year to year decrease in production since 1991. Production decreased in response to lower demand for many uses including: blast, container and specialty glass, filtration, foundry, recreational, traction sands and for silica used in the "whole grain filler/building products" category.

Exports of industrial sand and gravel dropped nearly 24% compared with 1995. However, the value of the exports increased about 7%, to $113 million. Also dropping, imports of industrial sand and gravel in 1996 were only 12% of the amount imported in 1995. The annual amount of imports has been consistently quite small but is composed mostly of many small shipments of high-value silicas. Domestic apparent consumption of industrial sand and gravel in 1996 was 26.4 million tons, unchanged from 1995. *(See table 1.)*

Legislation and Government Programs.—The regulation of respirable silica continued to concern miners and consumers of many minerals that contain crystalline silica, especially the industrial sand and gravel industry. The Occupational Safety and Health Administration (OSHA) listed crystalline silica as one of their top five priorities for formal rulemaking (Chemical and Engineering News, 1996d). Other regulatory government agencies, including the Mine Safety and Health Administration, and the Environmental Protection Agency continued to study, or planned to further study, silica related health concerns.

In 1996, OSHA began a national special emphasis program on crystalline silica, including extensive outreach and inspections, in order to reduce the potential threat of silicosis. To encourage voluntary protection measures, OSHA would conduct an outreach program for 60 days before proceeding with enforcement under existing OSHA standards (Ceramic Industry, 1996c).

Fiberglass, a product which is produced from silica, has also been scrutinized by some Government and private organizations. Public health concerns about fiberglass were addressed in a report released by the Natural Resources Defense Council, a New York City-based environmental research group. The group cited a study by the International Agency for Research on Cancer that claims fiberglass is a potential carcinogen (Engineering News Record, 1996b).

Production.—Domestic production data for industrial sand and gravel were developed by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 82 producers of industrial sand and gravel with 146 active operations. Of the 156 industrial sand and gravel operations surveyed, 119 (76%) reported to the USGS. Their combined production represented about 88% of the U.S. total published in table 1. The production of nonrespondents was estimated based on previously reported information and other factors. Of the 156 operations, 146 (94%) were active and 10 idle.

The Midwest (East and West North Central divisions) continued to lead the Nation with about 42% of the 27.8 million metric tons produced in the United States, followed by the South (South Atlantic, East and West South Central divisions) with about 35% and the West (Pacific and Mountain divisions) with 14%. *(See table 2 and figure 1.)*

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The five leading States in the production of industrial sand and gravel, in descending order of volume, were Illinois, Michigan, California, New Jersey, and Wisconsin. Their combined production represented 44% of the national total. Notable production changes occurred in Michigan which had a 8.8% decrease in production and New Jersey which experienced a 4.5% decrease, compared with 1995. Production in California, Illinois, and Wisconsin was virtually unchanged from 1995 to 1996. In 1996, nine States had increased production, 14 States had decreased production, and 14 States stayed about even compared with 1995. Alabama, Idaho, and Louisiana reported the largest increases while Georgia, Tennessee, Texas, and Virginia reported the largest decreases. *(See table 3.)*

About 77% of the industrial sand and gravel was produced by 49 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage, Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Nugent Sand Co. Inc., Simplot Industries Inc., Construction Aggregates Corp., W.R. Bonsal Co., and Short Mountain Silica Co. Their combined production, from 58 operations, represented 71% of the U.S. total. *(See tables 4 and 5.)*

Merger and acquisition activity continued in 1996 as Unimin Corp., of New Canaan, CT, solidified its number one position with the purchase of the Morie Company from South Jersey Industries. Morie, consistently ranked in the top 10 during the last decade, operated industrial and construction sand and gravel operations in Alabama, Georgia, New Jersey, and Tennessee.

Whibco Inc., of Leesburg, NJ, a top 20 producer, reported better than expected sales in 1996 and announced the reopening of their Wareham, Massachusetts plant, after a costly upgrade of the plant's facilities. The upgrades allow the company to comply with State and Federal environmental statutes and provide expanded services to their customers. The New England region has a small number of silica producers due to unfavorable geology and local land use patterns. Whibco also opened its new corporate office at 87 East Commerce Street in Bridgeton, NJ. (Strelczyk, 1997)

Granite Rock Co., of Watsonville, CA, took over the operations of Santa Cruz Aggregates Co. on January 1, 1996. Granite Rock, which had leased the property to Santa Cruz, decided not to renew the lease and assumed operations at that location. Beside continuing to service the glass and recreational sand needs of Santa Cruz Aggregate's customers, Granite Rock plans to expand into other markets, particularly construction-related markets.

New producers included with this report are Custom Aggregates and Grinding of Houma, LA, and TEC Minerals Co., of Romayor, TX.

Colorado Lien Co., Fort Collins, CO, reported the closure of their LaPorte, CO, mine and plant in February. The plant operated for 30 days in 1996 and produced sand for the container glass market.

Consumption.—Sand and gravel production reported by producers to the USGS was actually material used by the companies or sold to their customers. Stockpiled material was not reported until consumed or sold. Of the 27.8 million metric tons of industrial sand and gravel sold or used, 37% was consumed as glassmaking sand and 23% as foundry sand. Other important uses were frac sand (6%) and abrasive sand (5%). *(See table 6.)*

The production of industrial sand and gravel in the United States has developed in response to market location and vice versa as industry sometimes located near silica resources. Because silica deposits (or resources) are found throughout the United States, locating a consuming industry specifically to be near a silica source was not always a priority, although certainly a consideration. The auto industry was originally located in the Midwest near iron, coal, clay, and silica resources. Therefore, foundry sands were greatly exploited in Michigan, Ohio, Indiana, Illinois, and other regional States. This resulted in over 78% of the foundry sand being produced in the Midwestern region in 1996.

The glass industry, somewhat conversely, had to locate plants where they could minimize the shipping distance of finished glass products. Hence, glass plants were more evenly distributed as 39% of glass sand was produced in the Southern region, 33% in the Midwest, 16% in the West, and 12% in the Northeast, in 1996. To varying degrees, all silica production was similarly influenced as markets and consuming industries either forced the silica mining location or were forced to locate near the silica source.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was 37%. This is slightly less than in 1995 but still higher than in 1985 when glass markets consumed only 35% of silica sold.

The amount of sand sold for glass container production continued to decrease, falling nearly 9% from 1995 levels, while glass container shipments dropped 5.4% during the year (Ceramic Industry, 1997). Wide mouth container shipments were down 10% while narrow neck container shipments were only down around 3%. Sales of glass containers are negatively influenced by competition from plastics, metals, and other packaging materials. Glass sand sales are also negatively influenced by this competition and by the recycling of glass containers. Also contributing to the decrease in domestic glass container sales, imported glass containers are now about 8% of domestic apparent consumption (Glass Industry, 1997).

Flat glass, unlike container glass, continued to be a good growth prospect for silica sales. Sales of sand for flat glass production increased nearly 5% even though shipments of flat glass decreased about 3% (Ceramic Industry, 1997). This probably took place because flat glass demand did not decrease until the end of 1996, after glass sand purchases were made. Flat glass demand remained relatively strong due to a healthy housing market and modest growth in the sales of light vehicles.

Silica is used in ceramics in both whole grain and ground form. Generally, the whole grain is used in the ceramic body, while the ground silica is used to decrease viscosity and expansion coefficent in ceramic glazes and other ceramic applications. Beyond traditional ceramics, advanced ceramics,

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such as silicon nitride and silicon carbide, represent a growing market for silica and silica-based chemicals.

Silica is used in plastics as a filler, extender, and reinforcer. Specifically, it is used to thicken liquid systems, as a thixotropic agent, flatting agent, and is used to avoid plateout in polyvinyl chloride. As segregated for this survey, consumption of ground silica for filler was 192,000 tons and whole grain filler sales amounted to 1.23 million tons in 1996.

Specialty silicas are usually produced by means of chemical and thermal processing of natural silica, silicon metal, or as a byproduct of other mineral or chemical processing. Although the USGS did not specifically collect information for specialty silicas, their consumption does affect natural silica sales. Specialty silicas and silanes (silica chemicals), included, but were not limited to, colloidal silicas, fumed silica, fused silica and quartz, precipitated silica, silica gels, silicones, and ultra-high purity silica. These silicas are used in a variety of industries and products including abrasives, beverages, catalysts, coatings, electronics, encapsulants, food, health care, optics, paper and packaging, plastics, refractories, rubber, specialty coatings, textiles, water treatment, and many others. On table 6, industrial sand and gravel which would find its way into these specialty silicas is most likely reported in the categories "chemical" and "silicon metal." Silica sales for chemical production remained about equal to 1995's levels, at 650,000 tons. Reported sales of silica gravel for silicon and ferrosilicon production increased over 20% in 1996 compared with 1995. The main uses for silicon metal are in the manufacture of silanes, semiconductor grade silicon, and in the production of aluminum alloys.

Another use for silicates is the cleanup of soils contaminated with hazardous waste. PQ Corp., of Valley Forge, PA, a manufacturer of silicas and silicates, uses silicates with portland cement to solidify and stabilize soil at hazardous waste sites. The silicates act as physical and chemical binder, resist acid attack, and improve the overall economics of waste treatment (Chemical Marketing Reporter, 1996d).

Northeast.—Cumberland County, NJ, continued to be the largest source for the glass and foundry sand markets in the region. Unimin and U.S. Silica, which operated plants in the county, were among the largest producers of sand for these markets. U.S. Silica's plant in Huntingdon County, PA, also produced significant amounts of sand for the glass market. Unimin and Ricci Brothers Sand Co. Inc., Cumberland County, produced a major percentage of the abrasive blast sand in the region. Whibco's operation in Cumberland County, was also a large producer of foundry sand in the region.

Midwest.—Unimin's plants in La Salle and Ogle Counties, IL; LeSueur and Scott Counties, MN; Jefferson County, MO; and Columbia County, WI, were among the leaders in producing sand for all four major markets: the blast, foundry, frac, and glass sand markets. Fairmount Minerals, with major operations in Berrien and Van Buren Counties, MI, Geauga County, OH, and La Salle County, IL, was also a major producer of sand for the four major markets in the region. U.S. Silica's plant in La Salle County, IL, was a large producer for the glass and foundry markets and their St. Louis County, MO, operation was a large producer for the glass market. Construction Aggregates Corp., Ottawa County, MI; Nugent Sand Co. Inc., Muskegon County, MI; and Sargent Sand Co., Wexford County, MI; were all large producers for the foundry industry. Badger Mining, Jackson and Green Lake Counties, WI, was a major producer for the foundry and frac markets. Kaw Valley Sand and Gravel Co., Wyandotte County, KS, and All Purpose Sand Co., St. Louis County, MO, were major producers of blast sand. Oglebay Norton's plants in Knox and Perry Counties, OH, and Manley Brothers of Indiana, La Salle County, IL, were significant producers for the glass market.

South.—Unimin and U.S. Silica Co. were two of the largest producers of sand for the glass and foundry markets. Unimin's major plants were in Izard County, AR; Marion County, GA; Richmond County, NC; Pontotoc County, OK; Carroll County, TN; Johnson County, TX; and Frederick County, VA. U.S. Silica's Bullock County, AL; Johnston County, OK; Lexington County, SC; Limestone County, TX; and Morgan County, WV, operations were their major contributors for these markets. Cobb Industrial Corp., Red River Parish, LA; Custom Aggregates and Grinding, Inc., Terrebonne Parish, LA; Huey Stockstill Inc., Pearl River County, MS; Mid-State Sand and Gravel Co., Allen and East Baton Rouge Parishes, LA; and Specialty Sand Co., Newton County, TX, were large producers of blasting sand. W.R. Bonsal and Co. and B.V. Hedrick Gravel and Sand Co., Anson County, NC, and Martin Marietta Aggregates, Macon County, AL, produced a large percentage of the industrial gravel used in the production of silicon and ferrosilicon. Oglebay Norton, with two operations in McCulloch County, TX, was the largest producer of frac sand, and an important contributor of blast sand for the region. Whibco in Kershaw County, SC, was an important producer of foundry sand. APAC Arkansas Inc., Muskogee County, OK; and Short Mountain Silica Co., Hawkins County, TN, were important producers of glass sand.

West.—Owens-Illinois, Simplot Industries, Unimin, and Lane Mountain Silica were the largest producers of glass sand in the region, with major operations in Amador County, CA; Clark County, NV; Contra Costa County, CA; and Stevens County, WA, respectively. Lane Mountain Silica; Lone Star Industries Inc., Monterey County, CA; and P.W. Gillibrand Co., Ventura County, CA; were the major suppliers for the sand blasting industry in the region. Simplot Industries also supplied a large portion of the foundry sand consumed. FMC Corp., Power County, ID; Rhône-Poulenc Basic Chemicals Co., Beaverhead County, ID; and Monsanto Industrial Chemicals Co., Caribou County, ID, each produced industrial gravel for use as a flux in elemental phosphorus production. The Ashton Co., Pinal County, AZ, was the largest producer of silica for metallurgical flux in the region.

Recycling.—Recycling of silica sands was limited to some foundry sands, particularly those used for making cores and molds with no-bake resin-bonded sands, some abrasive and airblasting sands, and, increasingly, post consumer glass and scrap glass (cullet) that substitutes for batch mix (including

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industrial sand). Most glass recycling was restricted to container glass, with green and amber cullet consumed in greater amounts for glass production because it is more difficult to use cullet in flint batch mixes.

Glass container recycling was estimated at 38% of consumption in the United States for 1996. This included glass used in glascrete (cullet used in portland and asphalt concrete) and those that were refilled, and represents an increase from the 1995 rate of 37% (Glass Packaging Institute, 1997). The price for cullet varied based on region and grade (flint (clear), brown (amber), or green) and location. Cullet from consumers generally passes through a processor, who receives it from municipalities, counties, etc., and the processor then provides it to the glassmaker.

As the level of cullet used in glass production increases, so does the level of quality required. Contamination of cullet by ceramics and nonmagnetic materials is an increasing concern. Because of the increased use of recycled glasses, restrictions on the iron and chromium levels in glass sands have become stricter and the proportion of refractory particles allowed has been reduced to almost zero. The Fe_2O_3 content of a typical glass silica sand is now as low as 0.015% to 0.02% for flint glass manufacture and 0.1% to 0.15% for colored glass. Additionally, recycling of amber and green glass was substantially greater than flint glass and therefore lower grade deposits are in less demand.

Students and faculty at New York City-based Columbia University conducted research into glascrete with the objective to find a use for the roughly 100,000 tons of glass that city residents discard each year. The group hopes to develop stronger, longer-lasting concrete by adding certain types of glass. So far, the researchers have discovered that green glass strengthens and stabilizes concrete by minimizing a chemical reaction that takes place between the alkali in cement and the silica in certain aggregates (Engineering News Record, 1996c).

Besides glass, recycling of used foundry sands is also being researched. Neu Séchage Industriel, of D'Ussel, France, has developed a sand reconditioning system using natural gas combustion in a fluidized bed. The reconditioning process is based on heat treating the spent sand. This causes the additive resins to decompose and the oxidation of their base components to be converted into water vapor and carbon dioxide. A 95% recovery rate was reported (Journal of Metals, 1996).

On the negative side, recycling of silica refractories is hardly ever done. Because recycling these refractories requires crushing and grinding, silica dust is generated. The dust must be controlled according to hazardous material regulations and this makes the recycling prohibitively expensive.

International trends toward increased recycling of glass and foundries sands and innovative ideas on recycling other materials should influence greater recycling of silica products.

Transportation.—Of the total industrial sand and gravel produced, 61% was transported by truck from the plant to the site of first sale or use, down from 65% in 1995; 35% was transported by rail, up from 32% in 1995; 2% by waterway; and 1% was not transported. Because most of the producers did not report shipping distances or cost per ton per mile, no transportation cost data were available.

Prices.—Compared with that of 1995, the average value, f.o.b. plant, of U.S. industrial sand and gravel increased slightly to $17.88 per metric ton. Average unit values for industrial sand and industrial gravel were $18.51 and $10.76 per ton, respectively. Nationally, ground industrial sand used as fillers for rubber, paint, and putty, etc., had the highest value per ton ($112.10), followed by ground silica for molding and core facings ($57.95), silica for well packing and cementing ($51.33), ground silica sand used in ceramics ($45.32), ground sand used for fiberglass ($44.10), ground silica for scouring cleansers ($43.75), and silica for swimming pool filters ($43.00).

Industrial sand and gravel price changes were greatly mixed, some markets remained level, others had small increases or decreases, and still others experienced large increases or decreases. This situation was possible because although the silica was essentially the same, most markets were very independent from each other and price competition was influenced by availability, regulations and health concerns, and competition from other materials. Those end uses that sustained greater prices in 1996, compared with 1995, included: blasting, ceramics, fiberglass (ground), filtration, recreational, roofing granules and fillers, silicon carbide, and whole grain fillers. Silica for container and flat glass, fiberglass (whole grain), flux, frac, ground fillers, refractory, scouring cleansers, traction, and well packing and cementing experienced a decrease in unit value.

The average value per ton of industrial sand and gravel was highest in the South ($19.23), followed by the West ($18.47), the Northeast ($18.31), and the Midwest ($16.54). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, glass sand average value per ton varied markedly, from $19.03 in the West to $12.24 in the Midwest. Tighter supplies and higher production costs in the West and much greater competition in the Midwest, caused the difference in the cost of sand and gravel in these two regions. *(See table 6.)*

Foreign Trade.—Exports of industrial sand decreased nearly 24% from 1995, but the associated value increased about 7%. Export distribution is as follows: 64% went to Canada, 15% went to Europe, 11% went to Mexico, 7% went to Asia, and the remainder went to Central and South America, the Middle East, and Oceania.

Imports for consumption of industrial sand dropped to 7,000 tons, which represents only 12% of the imports of 1995. Silica imports vary greatly from year to year but are always rather insignificant. Canada supplied 71% of the silica imports for 1996, averaging about $107 per ton (including insurance and freight cost to the U.S. port). The total value of imports was $1.5 million, with an average of $214 per ton. Higher priced imports came from Australia, Belgium, Germany, Italy, Japan, Sweden, and the United Kingdom. *(See tables 7 and 8.)*

World Review.—World production of industrial sand and gravel, based on information usually provided by foreign

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Governments, was estimated to be 117 million metric tons, slightly less than in 1995. The United States was the leading producer followed by, in descending order, the Netherlands, Germany, Austria, Paraguay, and France. Most countries in the world had some production and consumption of industrial sand and gravel because it is essential to the glass and foundry industries. However, because of the great variation in descriptions and usage for silica sand and gravel, it was difficult to get reliable information. Beyond those countries listed, several other countries were believed to have had some type of silica production and consumption. *(See table 9.)*

Current Research and Technology.—Most of the research and process development reported in 1996 concerned new types and uses of glass but other important work continued involving chemicals, ceramics, and advanced materials.

Owens Corning, of Toledo, OH, announced a new glass fiber product. Dubbed CRATEC Chopped Strand 173X-10C 4mm, it is designed to enhance the performance of polyamide composite polymers, especially in under-the-hood automotive applications (Functional Filler and Fiber Markets, 1996).

Pilkington PLC, St. Helens, United Kingdom, has developed a new process that promises to use greater amounts of silica and silicon. The new process enables a reflective multilayer sandwich of silicon and silica coatings to be applied continuously by chemical vapor deposition as the glass is being manufactured. The new mirrors will be able to withstand harsher and more humid environments than conventional silvered mirrors (Chemical and Engineering News, 1996a).

A chemist at Argonne National Laboratory and his colleagues are engineering an alkali-tin-silicate glass that does not deteriorate, as normal glass does, when plutonium is dissolved into it (Science News, 1996).

A treatment facility that immobilizes high-level nuclear wastes in glass has begun operations at the Federal Government's Savannah River site in South Carolina. The first stainless steel canisters, measuring 10 feet tall by 2 feet in diameter, were filled in March. There are 34 million gallons of radioactive waste which will fill about 6,000 canisters (Chemical and Engineering News, 1996c).

The first canister of vitrified radioactive waste at the Department of Energy's West Valley, NY, site was produced July 9, 1997. Over 600,000 gallons of high-level radioactive waste at the site will be mixed into a glass and poured into stainless steel canisters that are identical to the ones used in South Carolina. When finished, about 300 containers of vitrified radioactive material will be produced (Engineering-News Record, 1996e).

AlliedSignal Ceramic Components of Torrance, CA, has developed a new silicon nitride. The ceramic was produced in its ongoing program to develop a high-temperature in situ reinforced silicon nitride for heat engine applications. The new material meets most of the program goals (Ceramic Industry, 1996b).

Silicon wafer surfaces can be rendered bioactive by simple wet-etching techniques new research shows. The research suggest that silicon "biochips" might be developed to bond directlty with living soft tissue and bone, with potential use in invasive medical and biosensing applications, intelligent drug delivery systems, and other electronic prosthetic devices (Chemical and Engineering News, 1996b).

Researchers have discovered a new form of silica nanoparticle that aggregate into a novel spiderweb-like microstructure and give off a bright blue glow when irradiated with ultraviolet light. The material shows promise for use in catalytic membranes, optical devices that emit blue light, and as an agent to increase the viscosity of polymers. The silica nanoparticles are produced by laser vaporization of polycrystalline silicon in an oxygen-containing atmosphere (Chemical and Engineering News, 1996f).

PQ Corp., a producer of zeolites (derived partially from silica) and other silanes, reportedly is working on and has developed new siliceous builders and other forms of silicates. They have recently introduced new products to some of the detergent manufacturers and are awaiting their evaluations (Chemical and Engineering News, 1996e).

Dow Corning Corp., of Midland, MI, has introduced two new silicone surfactants to improve pesticide performance. The new surfactants improve the wetting, spreading, and uptake of post emergence herbicides and other foliar-applied insecticides and fungicides (Chemical Marketing Reporter, 1996a).

Outlook.—The forecast range of total U.S. demand in the year 2000 is expected to be 26 to 30 million metric tons for industrial sand and gravel. Probable demand is expected to be about 29 million tons. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecast made by analysts and producers in the various markets.

Since 1987, annual demand for glass sand had fluctuated between 10.0 and 11.1 million tons. Shipments of glass containers were down 5.4% in 1996 from 1995. In the United States, there were 137 billion container units consumed in 1985 and 20% were glass containers. By 1995, 182 billion units were consumed in the United States and the glass percentage had dropped to 14%. The amount of sand consumed for container glass has generally decreased since 1985 mainly because some glass containers were being replaced by aluminum cans and plastic containers and also because the amount of glass being recycled was increasing. Additionally, many manufacturers of container glass were using thinner walls in glass containers, and this has lowered the amount of sand used. Glass container shipments were expected to be about 2% less in 1997 compared with 1996.

In reaction to the lessening demand for container glass, Anchor Glass, of Tampa, FL, announced the closure of their plants in Cliftwood, NJ, and Houston, TX. Anchor is the United States' third-largest manufacturer of glass containers. From 1990 through 1996, at least 14 container glass production plants have closed down in the United States, leaving 72 plants in the United States (Edwards and Harben, 1996).

In 1996, flat glass shipments fell 3% from 1995. This decrease occurred despite an increase in flat glass' primary

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markets: housing, up 7.7%, and automobile production, up 2.2%. However, the rate of growth for nonresidential construction slowed in 1996 (Ceramic Industry, 1997).

Guardian Industries, of Auburn Hills, MI, progressed on an expansion of its automobile glass plant in Millbury, OH. When completed, the plant will produce 5.5 million square feet of laminated glass each year (Glass Industry, 1996).

American Video Glass Co., a partnership formed by Sony Electronics Inc., Corning Inc., and Asahi Glass America Inc., announced plans to build a $300 million plant to manufacture television glass. The facility will be located on the site of Sony's Pittsburgh manufacturing center at Mount Pleasant, PA (Ceramic Bulletin, 1996).

Flat glass shipments are expected to be unchanged in 1997 compared with 1996 due to slowdown in housing starts and light vehicle sales. At the global level, world flat glass demand is forecast to grow over 4% per year to 2.4 billion square meters in 2000.

Growth prospects remain good for fiber and specialty glasses. A 1996 report from Business Communications Co. Inc., Norwalk, CT, forecasts that the total North American market for advanced and specialty glasses will exceed $3.7 billion by 2000. Demand for glass fiber reinforcements used in advanced composite materials is expected to grow by 9.6% through 2000. Growth was also expected in the market for electronic displays, such as liquid crystal displays (Industrial Minerals, 1996).

Made with glass, carbon, or aramid fibers, composite materials are usually polymers with fiber reinforcements. Today, these composites are used in the aerospace and chemical industries and they resist corrosion, impacts, parasites, and chemicals. Future growth will likely occur through the replacement of traditional materials such as concrete and steel. However, a lack of national standards covering design and fabrication of composites present hurdles for this changeover (Engineering News Record, 1996a).

Total demand for glass sand is expected to grow slowly through 2000. Probable demand for glass sand for 2000 was forecast to be 11.5 million tons, with a range of 9.5 to 12.5 million tons.

The use of foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling, though not clear, is thought to be increasing. Other materials or minerals compete with silica as foundry sand but these other "sands" usually suffer a severe price disadvantage. Based on these factors: foundry activity (mainly auto related), competing materials, and recycling, the probable forecast for silica foundry sand consumption in 2000 is expected to be 7.0 million tons, and the demand range is expected to be 6 to 7.5 million tons.

Frac sand sales in 1996 were about equal to those of 1995. The Baker-Hughes' cumulative drilling rig count comparing year to year data shows that 1996 stayed ahead of 1995's rig count from late February through the end of the year and ended the year about 12% ahead of 1995's week-by-week comparison. Although the greater rig activity in 1995 did not translate to greater frac sand sales, the trend towards increased activity throughout 1996 boded well for growth in frac sand sales. As has been the case when comparing oil and gas drilling, U.S. production of oil will likely suffer as imports continue to control a higher percentage of supply but natural gas production will likely maintain steady increases. Exports were an important market for frac sand as U.S. sand was shipped to locations throughout the world.

Based on these factors, demand is expected to grow slowly for this end use during the decade. Growth will be in response to strong exports and growing demand for natural gas but tempered by limited U.S. oil well demand. Probable demand for hydraulic fracturing sand for 2000 is expected to be 1.6 million tons, with a range of 1.4 to 1.7 million tons.

Even though the growth in semiconductor sales has slowed, the rate of growth is still near 20% annually, dropping from around 40% in recent years. Advanced Silicon Materials, Inc. announced plans for the construction of a $400 million polycrystalline silicon plant near Butte, MT (Chemical Marketing Reporter, 1996b). Polycrystalline silicon is the type of silicon that is grown from silica chemicals and used for semiconductor applications.

Hemlock Semiconductors Corp. has announced a $100 million expansion at its Hemlock, MI, plant. Hemlock plans to increase capacity at the plant by 40% to a total production of 5,000 tons of polycrystalline silicon per year (Chemical Marketing Reporter, 1996c).

Some semiconductor companies have reacted to the slowdown in semiconductor sales with slowdowns of their own. Micron Technology Inc., Boise, ID, has slowed the construction of its $2.5 billion semiconductor plant in Lehi, UT, and will complete the project on a 3- to 5-year time frame. The plant was originally planned to be finished by September 1996, but in February, Micron announced the slowdown (Engineering News Record, 1996d).

Ceradyne Inc., of Costa Mesa, CA, has installed its second pressure sintering facility solely dedicated to fabricating the advanced technical ceramic, sintered reaction bonded silicon nitride. Products which can be produced range from small cutting tool inserts to large precision semiconductor equipment components (Ceramic Industry, 1996a).

For specialty silicas, the silica route will usually be through the chemical and silicon metal categories and it is expected that the chemical and silicon metal categories should see better than average growth, probably in the 2% to 4% annual growth range. This positive forecast would be tempered if the specialty silicas producers are using a silica source other than industrial sand and gravel. The process for each type of silica is highly variable and certainly not well advertised and therefore it is difficult to determine the natural source and the processing route for the silica or silicate. Kline and Co. Inc. reported that producers of specialty silicas are scrambling to increase global capacity in anticipation of rising demand. Through 2000, the global market for specialty silicas is expected to grow at least 4% per year.

The United States is the largest producer and consumer of

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silica sand among the market economy countries and was self-sufficient in this commodity. Most of it is produced in the Eastern part of the United States, where the premier deposits and major markets are. A significant amount of silica sand is also produced in the West and Southwest, mostly in California and Texas. Domestic production is expected to continue to meet more than 99% of demand well beyond 2000. Imports, mostly from Australia, Canada, and Europe are expected to remain minor.

Because the unit price of silica sand is relatively low, except for a few end uses that required a high degree of processing, the location of silica sand deposits in relation to the market was an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supplied local markets with a limited number of products.

Several factors could affect supply-demand relationships for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for glass sand and foundry sand. These substitutes, mainly polymers and ceramics, would likely increase demand for ground silica, which is used as a filler in plastics; for glass fibers, which are used in reinforced plastics; and for silica, either chemical, whole grain, or ground, which are used to manufacture ceramics. Also, increased efforts to reduce waste and increase recycling could hinder glass sand demand. However, with advances in high tech materials, silica sand may see increased consumption for fiber optics and other silicon and glass compounds. Although developments could cause demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the more specialized sands.

An increase in the price of oil on the international market would stimulate domestic drilling and extraction from new and old oil deposits. This would increase demand for domestic hydraulic fracturing sand.

Concern over the use of silica as an abrasive due to health concerns and the imposition of stricter legislative and regulatory measures concerning silica exposure could decrease demands in many silica markets. Silica sand for use in the abrasive blast industry was being attacked as a health hazard as marketers of competing materials including garnet, slags, and olivine, pushed the use of their "safer" abrasive medium.

Development of more efficient mining and processing methods are expected to continue. This will enhance development of lower grade silica sand deposits closer to markets but not presently mined. Such developments are expected to increase silica sand reserves.

Tripoli

Tripoli, as broadly defined, is composed of extremely fine-grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers, but particles as small as 0.1 to 0.2 micrometers are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of yellow, brown, or red depending on the percentage of iron oxide.

Production.—A USGS annual survey of producers indicates that the output of crude tripoli produced domestically in 1996 was 98,000 tons with an estimated value of $4.1 million. In the United States, four firms are known to produce and/or process tripoli. Malvern Minerals Co., Garland County, AR, produces crude and finished material. Malvern also produces a black material from novaculite. American Tripoli Co. produces crude material in Ottawa County, OK, and finished material in Newton County, MO. Unimin Specialty Minerals Inc. in Alexander County, IL, produces crude and finished material. Keystone Filler and Manufacturing Co. in Northumberland County, PA, processes rottenstone, a decomposed fine-grained siliceous shale purchased from local suppliers. All of the aforementioned firms responded to the USGS survey.

Consumption.—The 1996 USGS annual survey of producers indicates that sales/use of processed tripoli decreased slightly in quantity to 79,600 tons with a value of $18.4 million. The large increase in value from 1995 to 1996 represents a correction reported by a producer and should not interpreted as an actual sudden jump in the price of tripoli. Unfortunately, corrected data for previous years were not available.

Tripoli has unique applications as an abrasive due to its hardness and because its grain structure lacks distinct edges and corners. It is a mild abrasive, making it suitable for use in toothpaste and tooth polishing compounds, industrial soaps, and metal/jewelry polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 25 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 1996, about 80% of tripoli output was used as a filler and extender in paint, plastic, rubber, caulking compounds, and enamel.

Tripoli primarily is used as a filler and extender in paints. These applications may account for as much as 85% of the tripoli used as a filler and extender. In exterior latex paints, tripoli also aids in tint retention, durability, leveling, and flowability. In enamels, it eases application and improves sheen. The controlled grain/particle size of tripoli in paints improves dispersal and promotes a more uniform coating. Additionally, paints with tripoli resist chemical agents and wear better than those in which water-ground whitings and other softer or more reactive fillers are used.

Plastics, rubbers, and resins each account for about 5% of the tripoli used as a filler/extender. Tripoli is used extensively in plastics for electrical uses because of its dielectric characteristics and its effects on flexibility and compression properties. Its chemical resistance, weatherability, and resistance to salt spray also are important to its use in plastics. The physical properties of tripoli allow high loading in most compounds, but its abrasiveness results in high wear in extruding nozzles and molds. The same properties that make tripoli useful as a filler and extender in plastics makes it valuable to the rubber and resin industries.

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Tripoli is almost entirely composed of crystalline silica, which can cause silicosis. Moreover, crystalline silica has been identified as a probable carcinogen by the International Agency for Research on Cancer and by other health research organizations. The OSHA is required to regulate materials containing more than 0.1% crystalline silica in accordance with its Hazard Communication Standard. Consequently, all tripoli shipments must be labeled by producers in compliance with OSHA regulations.

Price.—The average reported value of all tripoli sold or used in the United States was $231 per ton in 1996. The average reported value of abrasive tripoli sold or used in the United States during 1996 was $170 per ton; the average reported value of filler tripoli sold or used domestically was $246 per ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly over the next several years. Most of the existing markets are well defined and the probability of new uses is low.

Special Silica Stone Products

Silica stone products are abrasive tools/materials such as hones, whetstones, oilstones, stone files, grindstones, grinding pebbles, tube-mill liners, and deburring media. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. However, this report excludes products fabricated from such materials by artificially bonding the abrasive grains.

Production.—In response to a USGS production survey, 12 domestic firms reported that they quarried certain silica materials and/or manufactured silica stone products during 1996. Arkansas accounted for most of the value and quantity of production reported. Plants in Arkansas manufacture oilstones, whetstones, files, and deburring/tumbling media. Elsewhere, grindstones were manufactured in Ohio and tumbling/grinding media were produced in Wisconsin.

The industry has produced four main grades of Arkansas whetstone in recent years. The grades range from the high-quality Black Hard Arkansas Stone down to the Washita Stone. In general, the Black Hard has a porosity of 0.07% and a waxy luster, while Washita Stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products is a combination of household, industrial, leisure, and craft uses. Major household uses include the sharpening of knives and other cutlery such as scissors, shears, and lawn and garden tools. Leading industrial uses include the sharpening and honing of cutting surfaces, polishing of metal surfaces, and the deburring of metal and plastic castings. Recreational uses include the sharpening of sports knives, arrowheads, spear points, and fish hooks. Craft applications include sharping tools for wood carving, jewelry making, and engraving work. Also, silica stone files are used in the manufacture, repair, and modification of firearms.

Price.—The reported value of crude material suitable for cutting into finished products varied from $229 per ton to $1,140 per ton in 1996. The average value was $560 per ton. The average value of stone products made from crude material was $4.22 per pound.

Foreign Trade.—Silica stone products exported in 1996 had a value of at least $6.7 million. These exports were categorized as "hand sharpening and polishing stones" by the U.S. Department of Commerce, which collects trade data. This category accounted for most, if not all, of silica stone products exported in 1996.

The value of imported silica stone products in 1996 was at least $2.96 million. These imports were hand sharpening and polishing stones, which accounted for most or all of imported silica stone products in 1996. A portion of the finished products that were imported may have been made from crude novaculite produced within the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly over the next several years. Most of the existing markets are well defined and the probability of new uses is low.

Quartz Crystals

Electronic-grade quartz crystal is single-crystal silica which has properties that make it uniquely useful for accurate frequency controls, timers, and filters in electronic circuits. These devices are utilized for a wide variety of electronic applications in communications equipment, computers, aerospace hardware, instruments for military/commercial uses (e.g., altimeters and navigational aids), and consumer goods (e.g., clocks, television receivers, and games/toys). Such uses generate practically all of the demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used as windows and lenses in specialized devices including some lasers.

Natural quartz crystal primarily was used in electronic and optical applications until 1971, when it was surpassed by cultured quartz crystal. The use of natural quartz crystal for carvings and other gemstone applications continued; quartz crystal for such applications are covered in an annual Gemstones Mineral Industry Survey published by the USGS.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated more than 50 years ago when it gained wide use as an essential component of military communication systems during World War II. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of the latter for a national stockpile began.

As of December 31, 1996, the National Defense Stockpile (NDS) contained about 236,000 pounds of natural quartz crystal with a reported market value of more than $2.9 million. The stockpile has 11 weight classes for natural quartz crystal ranging from 200 grams to more than 10,000 grams. However, the stockpiled crystals primarily are in the larger weight classes.

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The larger pieces are suitable as seed crystals for cultured quartz crystal production. In addition, much of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be utilized in the same applications as cultured quartz crystal.

As cultured quartz crystal displaced natural quartz crystal in most applications, the Federal Government continued to assess its stockpile goals for the latter material. In the latest reports on the inventory of stockpile material, no quartz crystals were designated for retention. However, based on the figures reported for 1995 and 1996, no sales of natural quartz crystal occurred in 1996. Previously, quantities sold from the group that contains individual crystals in the NDS inventory that weighed 10 kilograms or more and could be used as seed material to generate cultured quartz crystal. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced its production to a very small output.

Production.—The USGS collects domestic production data for quartz crystal through a survey of the domestic industry. In 1996, the industry consisted of four cultured quartz crystal producers and one company that mined feed material, called lascas, for producing cultured crystal. Four of the five producers responded to the industry survey, representing over 95% of the lascas and cultured quartz crystal output shown in table 1.

Lascas Products, Jessieville, AR, is the only domestic company known to supply lascas for producing cultured quartz crystal. Coleman mined only during the summer months, but processed lascas throughout the year. After mining, crushing, and sizing, lascas is transported to the company's processing plant where operators rinse it in oxalic acid and then in deionized water to remove external contaminants. Finally, hand sorting, drying, and examination on a light table complete the necessary processing. The material is then shipped to cultured quartz crystal producers in 45-kilogram (100-pound) bags within 20,000-kilogram lots.

The following four U.S. companies produced cultured quartz crystal during 1996: Sawyer Research Products Inc. of Eastlake, OH; Thermo Dynamics Corp. of Merriam, KS; Motorola Inc. of Chicago, IL; and P. R. Hoffman Material Processing Co. of Carlisle, PA. Sawyer and Thermo Dynamics produced crystal bars for domestic and foreign firms in the crystal device fabrication industry. Motorola produced quartz crystal for internal consumption and domestic device fabricators. P.R. Hoffman reported external sales.

The aforementioned companies produce cultured quartz crystal using a hydrothermal process in large pressure vessels, known as autoclaves. Seed crystals (very thin crystals cut to exact dimensions) are mounted on racks and suspended in the upper growth region of the vessel. Lascas is loaded in an open-mesh wire basket that is placed in the bottom of the autoclave.

A solution of sodium hydroxide or sodium carbonate (the mineralizer), with additives such as lithium salts and deionized or distilled water is used to fill the vessel from 75% to 85% of its volume. The bottom half of the growing vessel is heated to temperatures averaging between 350° C to 400° C; the temperature of the top portion is maintained at 5° C to 50° C less, depending on the mineralizer used. At these temperatures, the solution expands and creates an internal pressure in the vessel between 10,000 and 30,000 pounds per square inch. Under these conditions, the lascas dissolves to create a solution saturated with silica. Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach their desired size. The process normally take 30 to 60 days for a 1-inch thick bar and longer for other types of crystal; at least one producer has made runs of about 180 days. The cultured crystals can be custom grown with specific properties.

The processing of quartz crystal for various end uses is the same whether natural or cultured seed crystal is used. However, producers must avoid seed crystals with defects that would pass on to new generations of cultured crystal. Natural quartz crystal is preferred as seed material to ensure that genetic defects will not be repeated in the succeeding generations.

Once produced, cultured crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness; electrodes are attached and the crystals are mounted in suitable holders. The final assembly, called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—The USGS collected 1996 domestic consumption data for quartz crystal through a survey of 30 U.S. operations in 11 States that fabricate quartz crystal devices. These companies represented virtually all of domestic consumption. Nineteen companies responded to the survey. Nonrespondent's consumption was estimated based on previous years' reports.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for military, aerospace, and commercial bandpass filter applications that require very high selectivity or in oscillator applications that require very high stability. In addition, for many applications requiring only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators also are used for many less demanding applications such as providing timing signals for electronic circuits in industrial, automotive, and consumer products.

Cultured quartz is used almost exclusively by the crystal device industry because of cost advantages. For resonator applications, raw quartz must be cut into thin wafers oriented precisely with the raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost

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universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining uses of natural electronic-grade material is in pressure transducers used in deep wells.

The quartz wafer must be cut too thinly for practical use at very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than wafer thickness, have become more important at these higher frequencies. These structures are called surface acoustical wave devices.

Most optical applications use quartz in the fused form as silica glass. Relatively small quantities of cultured quartz crystal are used directly for special optical considerations. Quartz crystal also has uses involving normally polarized laser beams; quartz retardation plates (especially quartz wave plates), Brewster windows and prisms, birefringent filters, and tuning elements are utilized in laser optics.

Prices.—The average value of as-grown cultured quartz was $49 per kilogram in 1996. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, was about $117 per kilogram. (Also note market value cited above for natural quartz crystal in the NDS.)

Foreign Trade.—The U.S. Department of Commerce, which is the major government source of U.S. trade data, does not provide specific import or export statistics on lascas. Some lascas reportedly was imported from Africa (probably Namibia) and Brazil in 1995. Imports and exports of all electronic-grade quartz crystal are shown in table 1.

World Review.—Cultured quartz crystal production is concentrated in China, Japan, Russia, and the United States with several companies producing crystal in each country. Smaller production capacity exists in Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, nations that formerly comprised the U.S.S.R., and Eastern European countries is unavailable. However, it is known that operations in Russia have significant capacity to produce synthetic quartz.

Outlook.—Demand for quartz crystal devices should continue to grow and, consequently, quartz crystal production should remain strong well into the future. Growth of the consumer electronics market (e.g., personal computers, electronic games, and cellular telephones) particularly in the United States, will continue to provide markets for domestic production. The growing global electronics market may require additional production capacity worldwide.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT U.S. SILICA STATISTICS 1/

		1992	1993	1994	1995	1996
Industrial sand and gravel: 2/						
Sold or used:						
Sand:						
Quantity	thousand metric tons	23,700	24,500	25,500	26,300	25,500
Value	thousands	$415,000	$436,000	$466,000	$480,000	$473,000
Gravel:						
Quantity	thousand metric tons	1,520	1,700	1,790	1,880	2,240
Value	thousands	$19,800	$18,500	$22,400	$21,900	$24,100
Total industrial:						
Quantity	thousand metric tons	25,200	26,200	27,300	28,200	27,800
Value	thousands	$434,000	$454,000	$488,000	$502,000	$497,000
Exports:						
Quantity	thousand metric tons	1,340	1,750	1,880	1,870	1,430
Value	thousands	$90,400	$91,000	$102,000	$106,000	$113,000
Imports for consumption:						
Quantity	thousand metric tons	164	44	24	59 r/	7
Value	thousands	$2,450	$2,440	$1,790	$2,730	$1,500
Processed tripoli: 3/						
Quantity	metric tons	76,200	78,300	82,300	80,100	79,600
Value	thousands	$14,100	$15,500	$10,900	$10,500	$18,400
Special silica stone:						
Crude production:						
Quantity	metric tons	1,730	528	873	979	1,290
Value	thousands	$239	$240	$821	$777	$722
Sold or used:						
Quantity	metric tons	340	267	487	374	410
Value	thousands	$4,550	$3,770	W	W	$3,810
Electronic and optical-grade quartz crystals:						
Production:						
Mine	thousand kilograms	778	454	544	435	435
Cultured	do.	407	394	294	351 r/	327

r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Puerto Rico excluded from all industrial sand and gravel statistics.
3/ Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC REGION 1/

	1995				1996			
Geographic region	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total	Quantity (thousand metric tons)	Percent of total	Value (thousands)	Percent of total
Northeast:								
New England	81	(2/)	$1,560	(2/)	110	(2/)	$1,770	(2/)
Middle Atlantic	2,400	9	42,900	9	2,280	8	42,000	9
Midwest:								
East North Central	10,400	37	161,000	32	10,200	37	159,000	32
West North Central	1,900	7	41,000	8	1,820	7	39,800	8
South:								
South Atlantic	4,070	14	76,300	15	3,820	14	73,400	15
East South Central	1,470	5	22,300	4	1,620	6	23,900	5
West South Central	4,110	15	84,600	17	4,100	15	86,300	17
West:								
Mountain	1,790	6	28,400	6	1,820	7	24,800	5
Pacific	1,960	7	44,000	9	2,010	7	46,000	9
Total	28,200	100	502,000	100	27,800	100	497,000	100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED
IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	1995		1996	
	Quantity	Value	Quantity	Value
Alabama	479	5,940	799	8,380
Arizona	334	2,910	323	2,890
Arkansas	W	W	W	W
California	1,710	38,300	1,760	40,500
Colorado	W	W	W	W
Florida	547	6,340	515	6,340
Georgia	574	7,060	313	5,650
Idaho	501	8,720	646	8,510
Illinois	4,410	67,500	4,460	66,400
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	572	10,500	706	12,100
Maryland	W	W	W	W
Massachusetts	--	--	W	W
Michigan	2,940	30,600	2,680	29,400
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	W	W	W	W
Montana	W	W	W	W
Nebraska	W	W	W	W
Nevada	W	W	W	W
New Jersey	1,760	31,000	1,680	30,300
New York	W	W	W	W
North Carolina	1,330	21,900	1,500	21,700
North Dakota	W	W	W	W
Ohio	1,270	28,800	1,270	29,800
Oklahoma	1,250	25,400	1,350	27,200
Pennsylvania	W	W	W	W
Rhode Island	W	W	W	W
South Carolina	839	20,500	761	19,500
Tennessee	918	14,700	747	13,900
Texas	1,600	40,300	1,420	38,200
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	W	W	W	W
Wisconsin	1,670	33,300	1,660	32,300
Other	5,500	109,000	5,190	104,000
Total	28,200	502,000	27,800	497,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED
STATES IN 1996, BY SIZE OF OPERATION 1/

Size range	Number of operations	Percent of total	Quantity (thousand metric tons)	Percent of total
Less than 25,000	26	18	238	1
25,000 to 49,999	15	10	533	2
50,000 to 99,999	26	18	1,670	6
100,000 to 199,999	30	21	3,820	14
200,000 to 299,999	14	10	3,150	11
300,000 to 399,999	7	5	2,270	8
400,000 to 499,999	10	7	4,050	15
500,000 to 599,999	6	4	2,940	11
600,000 to 699,999	5	3	2,910	10
700,000 and over	7	5	6,200	22
Total	146	100	27,800	100

1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1996, BY GEOGRAPHIC REGION

Geographic region	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Northeast:						
New England	1	--	--	--	1	2
Middle Atlantic	9	--	2	1	4	16
Midwest:						
East North Central	33	--	--	1	4	38
West North Central	5	--	--	--	6	11
South:						
South Atlantic	16	--	1	3	5	25
East South Central	9	--	--	--	2	11
West South Central	8	--	--	2	11	21
West:						
Mountain	7	2	2	--	--	11
Pacific	8	1	1	--	1	11
Total	96	3	6	7	34	146

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TABLE 6
INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 1996, BY MAJOR END USE 1/

Major use	Northeast			Midwest			South			West			U.S. total		
	Quantity (thousand metric tons)	Value (thousands)	Value per ton 2/	Quantity (thousand metric tons)	Value (thousands)	Value per ton 2/	Quantity (thousand metric tons)	Value (thousands)	Value per ton 2/	Quantity (thousand metric tons)	Value (thousands)	Value per ton 2/	Quantity (thousand metric tons)	Value (thousands)	Value per ton 2/
Sand:															
Glassmaking:															
Containers	860	$14,900	$17.28	1,620	$17,000	$10.54	1,610	$23,800	$14.75	1,100	$21,700	$19.78	5,180	$77,300	$14.92
Flat (plate and window)	W	W	16.24	923	10,300	11.19	1,520	22,800	14.95	W	W	16.74	2,980	42,000	14.09
Specialty	W	W	22.48	368	5,630	15.29	327	6,150	18.82	W	W	30.74	928	17,200	18.52
Fiberglass (unground)	W	W	13.46	459	6,390	13.93	193	4,030	20.88	W	W	18.21	825	13,300	16.11
Fiberglass (ground)	--	--	--	W	W	49.35	379	16,500	43.55	W	W	27.67	431	19,000	44.10
Foundry:															
Molding and core	347	6,590	18.98	5,070	62,100	12.26	970	13,500	13.97	76	1,630	21.42	6,460	83,900	12.98
Molding and core facing (ground)	--	--	--	W	W	57.95	--	--	--	--	--	--	W	W	57.95
Refractory	W	W	31.00	49	557	11.37	W	W	48.38	W	W	23.43	58	981	16.91
Metallurgical:															
Silicon carbide	--	--	--	84	2,210	26.33	--	--	--	--	--	--	84	2,210	26.33
Flux for metal smelting	--	--	--	--	--	--	W	W	2.00	W	W	5.88	W	W	5.82
Abrasives:															
Blasting	140	3,780	26.98	205	4,650	22.70	969	21,700	22.38	152	5,010	32.93	1,470	35,100	23.96
Scouring cleansers (ground)	--	--	--	W	W	45.14	W	W	34.00	--	--	--	W	W	43.75
Sawing and sanding	W	W	19.00	W	W	13.00	W	W	18.75	--	--	--	W	W	17.67
Chemicals (ground and unground)	W	W	18.90	W	W	12.45	234	5,850	25.01	52	1,050	20.15	643	12,000	18.63
Fillers (ground):															
Rubber, paints, putty, etc.	--	--	--	115	6,070	52.78	W	W	217.80	W	W	29.71	192	21,500	112.10
Whole grain fillers/building products	61	1,470	24.03	488	15,600	31.90	406	9,840	24.23	271	7,310	26.99	1,230	34,200	27.90
Ceramic (ground):															
Pottery, brick, tile, etc.	W	W	31.00	146	6,950	47.60	122	5,340	43.73	W	W	37.00	278	12,600	45.32
Filtration:															
Water (municipal, county, local, etc.)	59	1,670	28.31	80	2,060	25.74	99	1,110	11.23	73	2,700	36.96	310	7,540	24.32
Swimming pool, other	W	W	59.29	W	W	58.00	36	1,210	33.64	--	--	--	54	2,320	43.00
Petroleum industry:															
Hydraulic fracturing	--	--	--	1,150	37,900	33.01	W	W	31.38	W	W	31.30	1,530	49,900	32.62
Well packing and cementing	W	W	58.33	17	1,110	65.00	W	W	15.14	--	--	--	27	1,390	51.33
Recreational:															
Golf course (greens and traps)	100	1,440	14.42	218	3,320	15.23	214	2,510	11.71	163	3,250	19.95	694	10,500	15.16
Baseball, volleyball, play sand, beaches	93	921	9.90	8	116	14.50	28	344	12.29	36	800	22.22	165	2,180	13.22
Traction (engine)	W	W	14.06	133	854	6.42	120	1,530	12.74	W	W	19.90	307	3,280	10.68
Roofing granules and fillers	90	1,440	15.94	41	707	17.24	153	2,270	14.83	45	698	15.51	330	5,110	15.48
Other (ground silica)	9	279	31.00	W	W	34.12	W	W	16.75	46	1,000	19.26	XX	XX	XX
Other (whole grain)	601	10,500	6.09	559	7,360	11.93	811	17,000	12.03	1,060	18,000	23.96	XX	XX	XX
Total or average	2,360	42,900	18.21	11,800	196,000	16.54	8,280	171,000	20.65	3,070	63,100	20.53	25,500	473,000	18.51
Gravel:															
Silicon, ferrosilicon	--	--	--	W	W	23.40	W	W	12.43	--	--	--	686	9,400	13.70
Filtration	W	W	34.57	W	W	11.02	82	816	9.95	--	--	--	188	2,480	13.19
Nonmetallurgical flux	--	--	--	--	--	--	W	W	6.89	W	W	10.20	946	8,700	9.20
Other uses, specified	W	W	10.60	21	185	8.81	285	2,200	7.71	W	W	10.04	420	3,530	8.41
Total or average	31	832	26.84	183	2,950	16.10	1,260	12,600	9.94	762	7,760	10.18	2,240	24,100	10.76
Grand total or average	2,390	43,800	18.31	12,000	198,000	16.54	9,550	184,000	19.23	3,830	70,800	18.47	27,800	497,000	17.88

W Withheld to avoid disclosing company proprietary data; included in "U.S. Total" and/or "Total or average." XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Calculated using unrounded data.

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TABLE 7
U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995 Quantity	1995 F.a.s. value 2/	1996 Quantity	1996 F.a.s. value 2/
North America:				
Bermuda	(3/)	5	--	--
Canada	1,430	20,200	914	17,100
Mexico	129	5,270	136	9,300
Panama	12	172	15	254
Other	9	616	7	1,420
Total	1,580	26,200	1,070	28,000
South America:				
Argentina	9	1,210	8	1,140
Brazil	2	948	1	580
Peru	2	224	1	258
Venezuela	5	857	3	518
Other	3	432	17	580
Total	21	3,670	30	3,080
Europe:				
Germany	41	13,700	35	14,100
Italy	4	2,350	4	866
Netherlands	49	9,630	10	6,750
United Kingdom	6	1,960	4	1,970
Other	22	5,050	165	9,390
Total	122	32,700	218	33,100
Asia:				
Hong Kong	9	2,030	20	1,930
Japan	52	24,400	36	29,300
Korea, Republic of	12	3,800	16	4,360
Singapore	8	4,400	6	3,630
Taiwan	53	5,740	17	3,510
Other	8	1,880	7	3,240
Total	142	42,200	102	46,000
Middle East and Africa	3	824	6	2,050
Oceania:				
Australia	1	644	2	1,160
Other	(3/)	28	1	45
Total	1	672	3	1,200
Grand total	1,870	106,000	1,430	113,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995 Quantity	1995 C.i.f. value 2/	1996 Quantity	1996 C.i.f. value 2/
Australia	56 r/	1,580	(3/)	63
Belgium	(3/)	36	(3/)	5
Canada	1	146	5	536
Germany	(3/) r/	301	(3/)	163
Guyana	(3/)	12	--	--
Italy	--	--	(3/)	11
Japan	(3/)	218	(3/)	346
Mexico	--	--	(3/)	4
Russia	(3/)	6	--	--
Sweden	1	403	1	265
United Kingdom	(3/)	17	(3/)	51
Venezuela	(3/)	11	(3/)	56
Total	59 r/	2,730	7	1,500

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 9
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina	340	396	247 r/	286 r/	290
Australia e/	2,000	2,000	2,500	2,500	2,500
Austria	5,884	4,302	6,457	7,503	7,000
Belgium e/	2,480	2,480	2,480	2,500	2,300
Bosnia and Herzegovina	50	50	50	50 e/	50
Brazil e/	2,700	2,700	2,700	2,700	2,700
Canada	1,754	1,600 e/	1,600 e/	1,689 r/	1,668 p/
Chile e/	300	300	300	300	300
Croatia	40	23	31 r/	341 r/	44 4/
Cuba e/	450	400	300	300	300
Czech Republic	XX	1,758	1,957	1,993	1,900
Czechoslovakia 5/	2,010	XX	XX	XX	XX
Denmark (sales) e/	315	315	315	50 r/	50
Ecuador	36 r/	49 r/	34 r/	36 r/	36
Egypt e/ 6/	500	500	500	500	500
Estonia e/	30	25	25	25	25
Finland	169	167	72	75 e/	75
France e/	6,300	5,400	7,280	6,100 r/	6,500
Germany	10,706	9,768	10,840	7,600 r/	7,500
Guatemala e/	34 4/	27	27	29	30
Hungary 7/	1,350	440	512	320 r/	325
Iceland e/	5	5	5	5	4
India	1,316	1,148	1,252 r/	1,220 r/	1,250
Indonesia	400 e/	240	588 r/	279 r/	300
Iran 8/	756	932	950 e/	1,000 e/	1,000
Ireland e/	7	7	8	7	6
Israel e/	60	60	60	60	60
Italy e/	4,000	3,100 r/	2,700 r/	3,000 r/	3,000
Jamaica	20	21	18	20 e/	20
Japan	3,843	3,883	3,942	3,734 r/	3,557 4/
Kenya e/	12	12	12	12	12
Korea, Republic of e/	2	2	2	2	2
Latvia	110 e/	90 e/	76	64 r/	50

See footnotes at end of table.

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TABLE 9--Continued
INDUSTRIAL (SILICA) SAND AND GRAVEL: WORLD PRODUCTION BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Malaysia	579	355	231	288	269 4/
Mexico	1,129	1,310	1,360	1,293	1,469 4/
Netherlands	20,000 e/	20,000 e/	25,006	23,159 r/	24,000
New Caledonia e/	31	31	39	40	40
New Zealand	72 r/	49 r/	38 r/	31 r/	30
Norway	900 e/	900 e/	891 r/	963 r/	900
Pakistan	135	168	170 e/	170 e/	165
Panama e/	23 4/	23	23	23	23
Paraguay e/	2,000 r/	2,000 r/	2,000 r/	7,000 r/	7,000
Peru	152	115	100	100	100
Philippines	744	828	800 e/	800 e/	800
Poland	931	1,020	911	952	900
Portugal e/	5	5	5	5	5
Serbia and Montenegro	922	270	403	308 r/	300
Slovenia	310	210	210	210 e/	200
South Africa	1,750	1,738	1,920	2,180	2,167 4/
Spain	2,178	2,506 r/	2,577 r/	2,881 r/	2,800
Sweden e/	1,433 4/	1,500	1,500	1,500	1,500
Tanzania e/	4 4/	4	4	--	--
Thailand	594	459	471	326 r/	350
Turkey e/ 9/	510	350	415	310 r/	350
United Kingdom	3,615	4,000 e/	4,038 r/	3,600 e/	2,000
United States (sold or used by producers)	25,200	26,200	27,300	28,200	27,800 4/
Venezuela	703	753	141	598	748 4/
Zimbabwe 10/	77	61 r/	89 r/	174 r/	150
Total	112,000	107,000 r/	119,000	119,000	117,000

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ Table includes data available through July 2, 1997.

2/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas and China, among others, produce industrial sand, but current available information is not adequate to formulate estimates of production levels.

4/ Reported figure.

5/ Dissolved Dec. 31, 1992. All production for 1992 came from Czech Republic.

6/ Fiscal years beginning July 1 of that stated.

7/ For the reported volumetric quantity, see the U.S.Geological Survey Minerals Yearbook 1996, v. III.

8/ Fiscal years beginning Mar. 21 of that stated.

9/ Washed product.

10/ Includes rough and ground quartz as well as silica sand.

TABLE 10
PROCESSED TRIPOLI 1/ 2/ SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE

Use		1992	1993	1994	1995	1996
Abrasives	metric tons	18,600	19,400	39,000	19,300	W
Value	thousands	$2,780	$2,960	$5,170	$2,920	W
Filler 3/	metric tons	57,600	58,900	42,800	60,700	W
Value	thousands	$11,300	$12,600	$5,640	$7,580	W
Total quantity	metric tons	76,200	78,300	82,300	80,100	79,600
Total value	thousands	$14,100	$15,500	$10,900	$10,500	$18,400

W Withheld to avoid disclosing company proprietary data.

1/ Includes amorphous silica and Pennsylvania rottenstone.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes silica used in brake lining manufacturing.

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TABLE 11
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 1996

Company and location	Type of operation	Product
Arkansas Abrasives, Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Blue Mountain Whetstone Co., Hot Springs, AR	do.	Do.
Buffalo Stone Corp., Hot Springs, AR	Tumbling and sizing novaculite	Metal finishing media deburring media.
Cleveland Quarries Co., Amherst, OH	Stone cutting and finishing	Grindstones.
Gary Coleman, Jessieville, AR	Quarry	Crude novaculite.
Crow Stone Co.:		
Pearcy, AR	do.	Whetstones and oilstones.
Do.	do.	Crude novaculite.
Dan's Whetstone Co., Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do.	Quarry	Crude novaculite.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
The Kraemer Co.:		
Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Norton Company Oilstones:		
Hot Springs, AR	do.	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Smith Abrasives, Inc.:		
Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Taylor Made Crafts, Lake Hamilton, AR	Stone cutting and finishing	Whetstones and oilstones.

TABLE 12
SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE QUARTZ CRYSTAL STATISTICS 1/

(Thousand kilograms and thousand dollars)

	1992	1993	1994	1995	1996
Production:					
Mine	778	454	544	435	435
Cultured	407	394	294	351 r/	327
Exports (cultured): 2/					
Quantity	15	24	38	35	89
Value	$1,280	$2,260	$6,110	$10,900	$22,200
Imports (cultured): 2/					
Quantity	6	8	19	47	42
Value	$1,130	$2,250	$5,950	$10,800	$9,480
Apparent consumption e/	398	378	275	363 r/	280

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits.
2/ Excludes mounted piezoelectric crystals.

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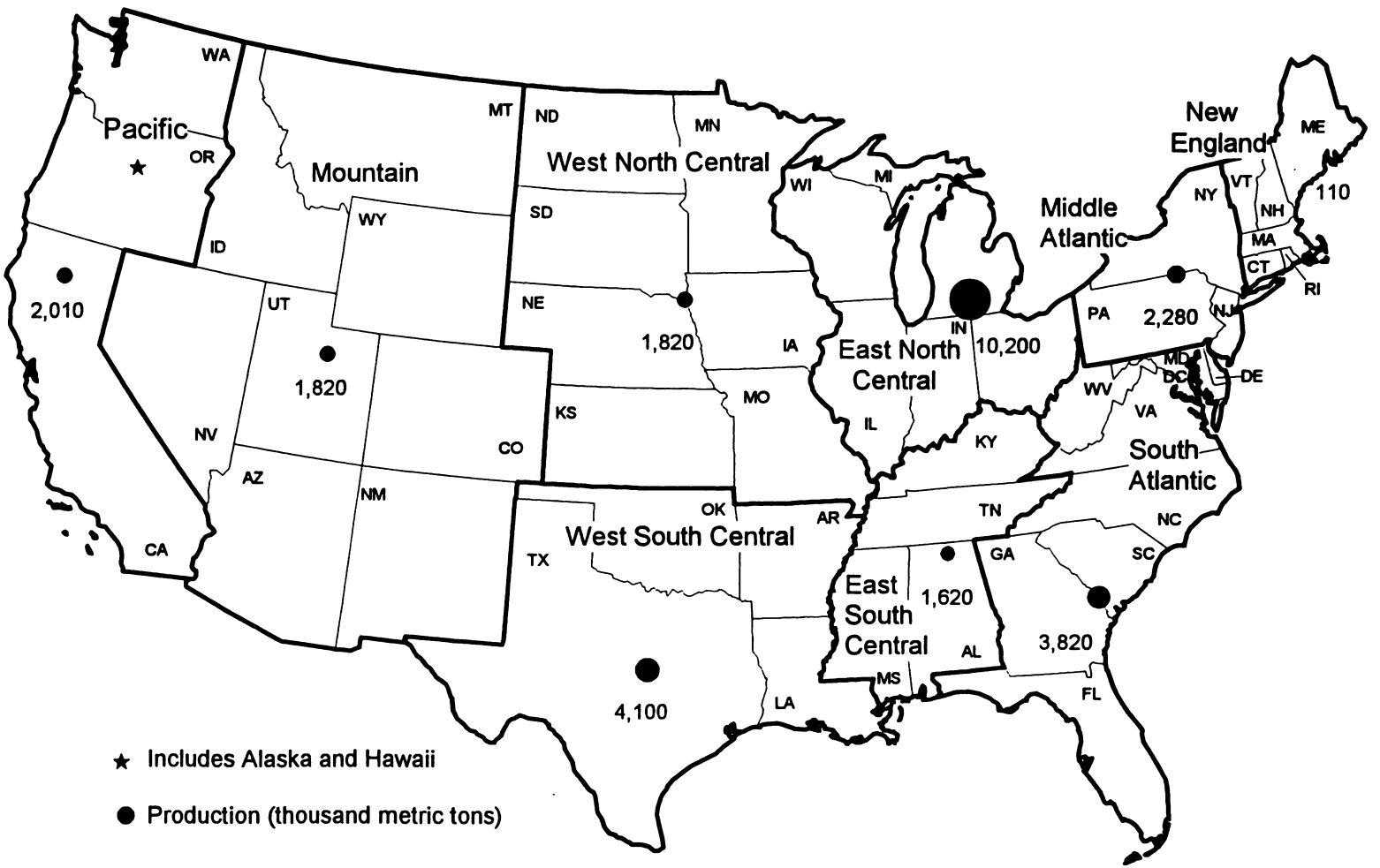

Figure 1 - Production of industrial sand and gravel in the United States in 1996, by geographic division

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SILICON

By Thomas S. Jones

Silicon (Si) is a light chemical element having metallic and nonmetallic characteristics. In nature, silicon combines with oxygen and other elements to form silicates. Silicon in the form of silicates constitutes more than 25% of the Earth's crust. Silica is a silicate consisting entirely of silicon and oxygen. Silica (SiO_2) as quartz or quartzite is used to produce silicon-based products for the aluminum, chemical, and iron and steel industries.

Silicon metal and ferrosilicon are referred to by the approximate percentage of silicon contained in the material and by the maximum amount of trace impurities present. There are two standard grades of ferrosilicon; one grade is about 50% silicon, and the other, 75% silicon by weight. Almost all ferrosilicon products are consumed by the iron and steel industry.

Metallurgical-grade silicon metal is used by the chemical, primary aluminum, and secondary aluminum industries. The products sold to these industries vary considerably in their specifications. The chemical and primary aluminum industries generally require more stringent specifications than those of the secondary aluminum industry. In addition, the chemical industry requires that the metal be ground into a fine powder rather than the lump form used by the aluminum industry.

The average annual dealer import price for ferrosilicon and silicon metal increased from that of 1995. On the basis of contained silicon, overall domestic silicon production increased to about 412,000 metric tons, and consumption of silicon decreased to about 594,000 tons.

Overall U.S. trade volume, gross weight, of silicon exports was up by about 3%, while overall trade volume of silicon imports was down by about 8%. The U.S. net import reliance for silicon products was estimated to be about 31%.

Legislation and Government Programs

The Generalized System of Preferences (GSP) program expired on July 31, 1995. On August 20, 1996, the President signed the Small Business Job Protection Act of 1996, which contained provisions entitled the GSP Renewal Act of 1996. The Act provides that GSP duty-free treatment will apply to eligible articles from designated beneficiary countries that are entered or withdrawn from warehouse for consumption on or after October 1, 1996, through May 31, 1997. Additionally, GSP duty-free treatment will have certain retroactive applications to articles entered after July 31, 1995, and before October 1, 1996 (U.S. Department of the Treasury, 1996). Under GSP, the United States grants duty-free access to goods from qualifying developing countries and territories. In 1996, U.S. import duties for selected silicon materials ranged from duty free to 7.6% ad valorem for most-favored-nation (MFN) status and from $0.044 per kilogram of contained silicon to 45% ad valorem for non-MFN status.

In a preliminary determination by the International Trade Administration (ITA) on July 25, silicon metal from Argentina was subject to dumping margins for the period of investigation of September 1, 1992, through August 31, 1993—8.52% for Electrometalurgica Andina, 24.62% for Silarsa S.A., and 17.87% for "all others" (U.S. Department of Commerce, 1996b).

On September 5, the ITA made a final determination that silicon metal from Brazil was subject to dumping margins for the period of investigation of July 1, 1992, through June 30, 1993—16.81% for Companhia Brasileira Carbureto de Calcio (CBCC) and 31.60% for Rima Electrometalurgia S.A. (RIMA) (U.S. Department of Commerce, 1996c). The ITA also made a preliminary determination that silicon metal from Brazil was subject to dumping margins for the period of investigation of July 1, 1993, through June 30, 1994—57.32% for CBCC, 31.60% for RIMA, and 9.29% for Camargo Correa Metais S.A. (CCM) (U.S. Department of Commerce, 1996e). Additionally, the ITA made a preliminary determination that dumping margins exist for silicon metal from Brazil for the period of investigation of July 1, 1994, through June 30, 1995—7.54% for CBCC, 2.12% for Companhia Ferroligas Minas Gerais Minasligas, 9.95% for Eletrosilex Belo Horizonte, 3.67% for RIMA, and 93.2% for CCM (U.S. Department of Commerce, 1996d).

On November 22, the ITA made a final determination that ferrosilicon from Companhia de Ferro Ligas da Bahia of Brazil would be subject to a dumping margin of 0.05% for the period of investigation of August 16, 1993, through February 28, 1995 (U.S. Department of Commerce, 1996a).

American Alloys Inc. and Elkem Metals Co. were put on probation for 1 year and received fines of $100,000 and $1,000,000, respectively, as a consequence of their having entered guilty pleas to charges of having conspired to fix prices of ferrosilicon. These sentences were an outgrowth of an investigation by the U.S. Department of Justice of an alleged conspiracy by some domestic producers to fix prices of commodity ferrosilicon products sold in the United States during 1989-1991. A third company, SKW Metals & Alloys Inc., was indicted for allegedly conspiring to fix prices of silicon metal as well (American Metal Market, 1996b; Ryan's Notes, 1996b).

Production

Overall gross production of silicon products in the United

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States increased by about 3% compared with that of 1995. Production of silicon metal was up by about 7%, and production of ferrosilicon and miscellaneous alloys was up slightly. Overall shipments of silicon-containing products were up slightly. Producer stocks of silicon-containing materials rose by more than 4% overall.

Domestic production data for silicon are derived from monthly and annual voluntary surveys and estimates for nonrespondents by the U.S. Geological Survey (USGS). The "Silicon Alloys" survey canvasses the operations listed in table 3. The figures in table 2 represent 100% of the production and shipments from these operations. *(See tables 1, 2, and 3.)*

Production of silicon metal and silicon alloys is extremely power intensive, requiring a power input for some operations of as much as 14,000 kilowatt-hours per ton of silicon content.

The location of ferrosilicon and silicon metal smelters is usually determined by balancing marketing costs against processing costs. Principal elements in the cost of silicon and ferrosilicon production are (1) delivered costs of the ore (quartz or quartzite), (2) energy cost, (3) cost of reductant coke or low ash coal, (4) cost of iron in the form of steel scrap, if required, and (5) labor.

Recovery of silicon from secondary sources is not generally practiced. The only secondary possibility is recovery from scrap metal. Any value of contained silicon is, however, incidental to the value of the primary metal. In 1996, the average price for silicon contained in ferrosilicon was about $0.63 per pound, and the average price for silicon metal was about $0.90 per pound. For the future, recycling of silicon in the form of ferrosilicon and silicon metal is expected to be insignificant.

In early May, the board of directors of Applied Industrial Materials Corp. (AIMCOR), Pittsburgh, PA, announced that the company had not only halted plans to sell off its metals group, but planned to invest capital in the group. The decision was influenced by improved market conditions, and the group's stronger performance and improved operating efficiencies (American Metal Market, 1996a). In late September 1993, AIMCOR had announced plans to sell off the company's metals and minerals groups, which included a ferrosilicon production facility in Bridgeport, AL.

In a joint venture with its subsidiary Kojundo Silicon, Mitsubishi Materials Corp. (Japan) announced plans to build a polycrystalline silicon (polysilicon) production plant in Mobile, AL. Mitsubishi will provide 80% of the capital needed for the $25 million venture, and Kojundo will provide the remaining 20%. Initial plant annual production capacity is anticipated at about 1,000 tons of polysilicon with potential capacity of up to 3,000 tons by the third year of operation (Roskill's Letter from Japan, 1996). Polysilicon is used mainly in the electronics industry in semiconductor devices.

Hemlock Semiconductor Corporation, Hemlock, MI, a joint venture between Dow Corning Corp., Shin-Etsu Handotai Co., and Mitsubishi Materials Corp., announced plans for a $100 million expansion at Hemlock's polysilicon plant. The expansion reportedly will increase annual production capacity at the plant by 40% to about 5,000 tons of polysilicon (Chemical Marketing Reporter, 1996).

Advanced Silicon Materials Inc. (ASIMI), Moses Lake, WA, plans to increase its annual polysilicon production capacity by 3,800 tons at Butte, MT. The construction will be in two phases. The $250 million first phase began in early 1996 and will have a workforce of about 165 people when operational in early 1998. The second phase will begin in 1997 and will have an additional 100 people when completed in 1999. Also, ongoing expansion at ASIMI's Moses Lake polysilicon operation was expected to increase annual production capacity at that facility from 1,200 to 2,100 tons by yearend 1996 (Advanced Silicon Materials Inc., 1996).

Consumption

The aluminum industry used silicon metal in the production of wrought and cast products, and ferrosilicon was used primarily as a deoxidizing and alloying agent in the production of iron and steel products. Metallurgical-grade silicon metal also was used as the basic raw material in the manufacturing of many chemical products and intermediates, such as silicones and silanes.

U.S. apparent consumption of silicon metal and silicon-containing ferroalloys was estimated to be about 594,000 tons of contained silicon, a decrease from that in 1995. Consumption of silicon metal was estimated to be about 233,000 tons, and consumption of ferrosilicon and miscellaneous silicon alloys was estimated to be about 361,000 tons. Compared with that of 1995, consumption of silicon metal increased by about 2%, and consumption of ferrosilicon and miscellaneous silicon alloys decreased by about 5%. Ferrosilicon and miscellaneous silicon alloys continued to account for more than 60% of all the silicon materials consumed, based on silicon content.

Prices

Demand for metallurgical-grade silicon alloys and metal is determined by the level of activity in the steel, ferrous foundry, aluminum, and chemical industries. As a result, prices tend to vary widely with changes in demand and supply.

The overall Platt's Metals Week "dealer import" price, posted in cents per pound of contained silicon, for 50%- and 75%-grade ferrosilicon increased by about 10% and 7%, respectively, compared with that in 1995. *(See table 1.)* The import price for 50%-grade ferrosilicon fell slightly from a range of $0.64 to $0.66 per pound to a range of $0.63 to $0.65 in mid-January, where it remained through yearend. The import price for 75%-grade ferrosilicon started the year at a range of $0.63 to $0.645 per pound, fell to $0.62 to $0.64 through September, and then retreated to a range of $0.54 to $0.58 by yearend. The fall in price in the fourth quarter was attributed to a decline in demand from the steelmaking sector.

The overall Platt's Metals Week "dealer import" price for silicon metal, posted in cents per pound of contained silicon, increased by almost 30% compared with that of 1995. *(See table 1.)* The import price for silicon metal started the year at a

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range of $0.75 to $0.77 per pound, rose to $0.93 to $0.98 by mid-June, and then fell to $0.85 to $0.88 by yearend. Silicon metal prices were influenced by a strong demand from the chemical sector and antidumping duties imposed in the United States.

Foreign Trade

U.S. exports of ferrosilicon increased by almost 25% on the basis of gross weight compared with that of 1995, and total value of exports was up by about 14%. *(See table 5.)* Canada and the United Kingdom were the major recipients of the materials, with about 66% of the total. Silicon metal exports decreased overall by more than 30% on the basis of gross weight, with the total value of the exports up by about 7%. More than 60% of the total was shipped to Canada, Japan, the Republic of Korea, and Malaysia.

U.S. imports of silicon-containing alloys were down by about 5% compared with that of 1995. *(See table 6.)* The total value of the exports was up by about 13%. Imports of ferrosilicon categorized as "55% to 80% silicon, other" decreased by about 10% on the basis of gross weight, with the total value for this category increasing by about 9%. Brazil, Iceland, and Norway remained the leading suppliers for this category, with more than 70% of the total. Imports of ferrosilicon categorized as "Other," which included all ferrosilicon of less than 55% silicon content, increased by more than 30%, with Canada accounting for more than 60% of the imports. Norway accounted for about 38% of total ferrosilicon imports.

Overall imports of silicon metal products declined by about 15%, with the total value of imports up by about 20%. Imports of silicon metal categorized as "99.00% to 99.99% silicon" decreased by about 10%, with Brazil, Canada, and France providing about 75% of total volume and value. Imports of "Other" silicon metal decreased by about 20%, with Russia supplying almost 70% of volume and value for this category. Brazil, Canada, France, and Russia accounted for more than 70% of total silicon metal imports.

The schedule of tariffs applied during 1996 to U.S. imports of selected silicon materials can be found in U.S. International Trade Commission (1995).

The U.S. net import reliances for ferrosilicon and silicon metal products were estimated to be 33% and 26%, respectively, compared with 38% and 30%, respectively, in 1995. The overall import reliance for silicon products was estimated to be 31% compared with 35% in 1995.

World Review

World production of ferrosilicon, was estimated to be about 3.9 million tons compared with about 4 million tons in 1995. The major producers were, in decreasing order, China, Norway, the United States, Russia, Ukraine, Brazil, Kazakstan, and France, accounting for more than 80% of total production. For the same period, production of silicon metal, excluding that of China, was estimated at about 652,000 tons compared with about 577,000 tons in 1995. Australia, Brazil, France, Norway, Russia, South Africa, and the United States accounted for about 95% of total production. The reader is referred to the annual review for 1996 for Ferroalloys in the Mineral Industry Surveys series of the USGS for annual world production of ferrosilicon and silicon metal, by country.

Western world consumption of ferrosilicon in 1996 was estimated by CRU International Inc., London, England, to be more than 2.3 million tons. The major consuming countries were, in decreasing order, Japan, the United States, Germany, Italy, France, and the United Kingdom, accounting for about 60% of the total. For silicon metal, Western world consumption was estimated to be more than 820,000 tons, an all-time high. The major consuming countries were, in decreasing order, the United States, Japan, Germany, the United Kingdom, France, and Italy, accounting for almost 80% of the total.

Outlook

Demand for silicon metal is driven by consumption in the aluminum and chemical industries. U.S. secondary aluminum producers were predicting a 3% to 5% increase in silicon metal demand in 1997. Within the chemical industry, silicon metal is used to produce a wide variety of silicone-based products and intermediates. Industry sources indicate that demand for silicon metal in the chemical sector is expected to rise by 8% to 10% in 1997. By 2005, Western world silicon metal consumption in the aluminum sector is expected to be about 626,000 tons, and consumption in the chemical sector will be about 676,000 tons (Ryan's Notes, 1996a, 1997).

The demand trend for ferrosilicon follows the trend of the iron and steel industry. The reader is referred to the outlook section of the annual review for 1996 for Iron and Steel in the Mineral Industry Surveys series of the USGS for discussion of the outlook for the steel industry. The industry uses ferrosilicon for deoxidation of molten metal and as an alloying agent. The annual growth rate for world steel consumption through 2000 is expected to be almost 2%. Most growth will occur in China; other Asian countries, with the exception of Japan; and Latin America. Asia was projected to account for 47% of world steel consumption by 2000 (Iron & Steelmaker, 1996).

For 1997, it is estimated that domestic production of silicon-containing ferroalloys and metal will be more than 400,000 tons and that U.S. apparent consumption will be about 600,000 tons.

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TABLE 1
SALIENT SILICON STATISTICS 1/

(Thousand metric tons of silicon content unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production	370	367	390	396	412
Exports:					
Ferrosilicon	30	21	20	22	27
Silicon metal	8	10	12	25	17
Imports for consumption:					
Ferrosilicon	161	141	147	158	148
Silicon metal	32	71	108	92	79
Apparent consumption:					
Ferrosilicon	337	335	360	381	361
Silicon metal	195	222	256	228	233
Price, average per pound Si: 2/					
Ferrosilicon, 50% Si	$0.369	$0.408	$0.439	$0.579	$0.640
Ferrosilicon, 75% Si	$0.354	$0.406	$0.408	$0.581	$0.622
Silicon metal	$0.600	$0.664	$0.641	$0.695	$0.897
World: Production (gross weight): e/					
Ferrosilicon	4,100	4,000	3,800 r/	4,000 r/	3,900
Silicon metal	570 r/	560 r/	560 r/	580 r/	650

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits.
2/ Platt's Metals Week dealer import prices.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILVERY PIG IRON, FERROSILICON, AND SILICON METAL IN THE UNITED STATES IN 1996 1/

(Metric tons, gross weight, unless otherwise specified)

Material	Silicon content (percentage)		Producers' stocks, Dec. 31, 1995	Gross production 2/	Net shipments	Producers' stocks, Dec. 31, 1996
	Range	Typical				
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon	25-55	48	19,900	182,000	116,000	22,700
Do.	56-95	76	19,300	132,000	139,000	16,900
Silicon metal (excluding semiconductor grades)	96-99	98	5,080	175,000	174,000	5,590
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	11,400	110,000	95,900	13,000

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.

TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND/OR SILICON METAL IN THE UNITED STATES IN 1996

Producer	Plant location	Product 1/
American Alloys Inc.	New Haven, WV	FeSi and Si.
American Silicon Technologies	Rock Island, WA	Si.
Applied Industrial Minerals Corp.	Bridgeport, AL	FeSi.
Elkem Metals Co.	Alloy, WV	Si.
Globe Metallurgical Inc.	Beverly, OH	FeSi and Si.
Do.	Niagara Falls, NY	FeSi and Si.
Do.	Selma, AL	Si.
Do.	Springfield, OR	Si.
Keokuk Ferro-Sil Inc.	Keokuk, IA	FeSi and silvery pig iron.
Simcala Inc.	Montgomery, AL	Si.
SKW Metals and Alloys Inc.	Calvert City, KY	FeSi.

1/ FeSi, ferrosilicon; Si, silicon metal.

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TABLE 4
REPORTED CONSUMPTION, BY MAJOR END USE, AND STOCKS OF SILICON ALLOYS AND METALS IN THE UNITED STATES IN 1996 1/ 2/

(Metric tons, gross weight, unless otherwise specified)

Silicon content (percentage)	Silvery pig iron	Ferrosilicon 3/				Silicon metal	Miscellaneous silicon alloys 4/	Silicon carbide 5/
Range	5-24	25-55	56-70	71-80	81-95	96-99	--	63-70
typical	18	48	65	76	85	98	48	64
End use								
Steel:								
Carbon	--	16,600	--	22,400	(6/)	(6/)	(6/)	(6/)
Stainless and heat-resisting	--	(6/)	--	32,900	(6/)	(6/)	(6/)	--
Other alloy	(6/)	5,520	--	(6/)	(6/)	(6/)	(6/)	(6/)
Tool	--	--	--	2,800	(6/)	--	(6/)	--
Unspecified	27	7,270	--	26,800	558	12,700	2,410	593
Total	27	29,400	--	84,900	558	12,700	2,410	593
Cast irons	21,800	84,600	1,450	25,700	665	W	W	28,700
Superalloys	--	W	W	W	33	W	--	--
Alloys (excluding superalloy and alloy steel)	W	W	--	W	--	W	--	W
Miscellaneous and unspecified	(7/)	2,690	(7/)	433	(7/)	233,000 8/	116,000	(7/)
Grand total	21,800	117,000	1,450	111,000	1,260	246,000	119,000	29,300
Consumers' stocks, December 31	1,170	5,470	193	8,300	50	2,810	2,000	1,080

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes U.S. Geological Survey estimates.
3/ Includes briquets.
4/ Primarily magnesium-ferrsilicon but also includes other silicon alloys.
5/ Does not include silicon carbide for abrasive or refractory uses.
6/ Included with "Steel: Unspecified."
7/ Included with "Cast irons."
8/ Includes silicones, silanes, fumed silica, and other chemicals.

TABLE 5
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1996 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Australia	49	34	$81,100
Brazil	164	99	224,000
Canada	8,150	4,890	6,490,000
Germany	82	57	115,000
Japan	18	11	22,800
Korea, Republic of	887	532	789,000
Malaysia	50	38	79,200
Mexico	3,020	1,890	2,670,000
Venezuela	27	16	22,500
Total	12,400	7,560	10,500,000
Other ferrosilicon:			
Australia	1,720	860	1,600,000
Canada	10,700	5,340	8,420,000
China	413	240	598,000
India	1,660	829	2,990,000
Japan	4,840	2,420	8,030,000
Korea, Republic of	1,180	588	1,450,000
Mexico	1,670	827	1,560,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1996 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Other ferrosilicon--Continued:			
Taiwan	238	119	280,000
Turkey	394	197	395,000
United Kingdom	15,100	7,560	8,670,000
Other	1,360	681	1,570,000
Total	39,300	19,700	35,600,000
Total ferrosilicon	51,700	27,200	46,100,000
Metal:			
More than 99.99% silicon:			
China	77	77	$3,350,000
Denmark	45	45	3,810,000
Germany	79	79	4,180,000
Italy	50	50	1,140,000
Japan	1,450	1,450	88,900,000
Korea, Republic of	633	633	27,700,000
Malaysia	179	179	45,100,000
Netherlands	39	39	1,840,000
Poland	31	31	1,380,000
Taiwan	50	50	1,980,000
Other	122	122	8,330,000
Total	2,750	2,750	188,000,000
99.00% - 99.99% silicon:			
Belgium	18	18	25,200
Germany	24	23	50,700
Ghana	118	117	229,000
Israel	335	332	786,000
Japan	307	305	854,000
Korea, Republic of	1,320	1,310	1,860,000
Malaysia	2,270	2,250	3,200,000
Mexico	267	265	441,000
Trinidad and Tobago	200	198	138,000
United Kingdom	283	280	399,000
Other	44	43	63,200
Total	5,180	5,140	8,050,000
Other silicon:			
Australia	185	179	257,000
Canada	3,260	3,170	3,440,000
China	492	478	660,000
Germany	344	334	499,000
Hong Kong	258	250	347,000
Japan	969	940	2,130,000
Korea, Republic of	363	352	633,000
Mexico	1,130	1,100	1,870,000
Taiwan	1,180	1,140	1,630,000
United Kingdom	267	260	384,000
Other	627	609	1,350,000
Total	9,080	8,820	13,200,000
Total silicon metal	17,000	16,700	209,000,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1996 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
55% - 80% silicon, more than 3% Ca:			
Canada	1	1	$1,590
Egypt	708	517	620,000
France	330	204	466,000
United Kingdom	27	19	155,000
Total	1,070	740	1,240,000
55% - 80% silicon, Other:			
Brazil	18,400	14,000	16,100,000
Canada	4,800	3,630	4,350,000
Egypt	9,480	6,750	8,010,000
Iceland	33,400	25,300	29,800,000
Italy	4,400	3,280	3,660,000
Macedonia	6,750	5,060	5,610,000
Norway	76,000	57,300	71,800,000
Poland	11,600	8,660	9,740,000
Romania	4,000	3,000	3,320,000
South Africa	3,590	2,750	3,230,000
Other	7,910	5,900	8,760,000
Total	180,000	136,000	164,000,000
80% - 90% silicon:			
Argentina	1,720	1,390	1,530,000
Canada	19	15	12,800
Total	1,740	1,400	1,540,000
More than 90% silicon:			
Italy	95	91	111,000
Romania	82	77	94,900
Total	177	168	206,000
Magnesium ferrosilicon:			
Brazil	5,010	2,300	4,840,000
Canada	1,620	772	1,330,000
China	72	19	73,400
Germany	66	33	172,000
Japan	132	55	285,000
Norway	2,010	926	2,530,000
Total	8,910	4,100	9,230,000
Other ferrosilicon:			
Brazil	390	184	439,000
Canada	10,700 2/	3,170	5,790,000
China	999 3/	150	120,000
Egypt	2,260	1,190	823,000
Mexico	1	(4/)	1,300
Norway	1,310	647	1,010,000
Poland	1,210	588	594,000
South Africa	9	2	7,550
United Kingdom	5	2	18,700
Total	16,900	5,930	8,810,000
Total ferrosilicon	209,000	148,000	185,000,000

See footnotes at the end of table.

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TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1996 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Metal:			
More than 99.99% silicon:			
Australia	40	40	$78,800
China	39	39	6,400,000
Germany	725	725	38,900,000
Italy	183	183	18,700,000
Japan	249	249	11,100,000
Korea, Republic of	185	185	9,750,000
Russia	24	24	3,680,000
Taiwan	12	12	576,000
Ukraine	12	12	609,000
United Kingdom	33	33	1,750,000
Other	16	16	788,000
Total	1,520	1,520	92,400,000
99.00% - 99.99% silicon:			
Australia	3,810 5/	3,760	5,970,000
Brazil	10,300 6/	9,700	17,300,000
Canada	12,800	12,700	20,000,000
China	183	181	230,000
France	6,930	6,880	11,900,000
India	1,130	1,120	1,860,000
Norway	2,010	2,000	3,870,000
Romania	492	489	596,000
South Africa	1,280	1,270	1,910,000
Spain	860	852	1,390,000
Other	185	184	404,000
Total	40,000	39,100	65,400,000
Other silicon:			
Brazil	618	595	1,010,000
Canada	779	761	1,280,000
China	3,210 7/	3,020	3,860,000
India	1,130	1,090	1,880,000
Japan	282	270	355,000
Macedonia	1,100	1,080	1,830,000
Romania	344	336	459,000
Russia	27,900 8/	26,100	38,600,000
South Africa	3,510	3,440	4,830,000
Spain	397	389	632,000
Other	1,080 9/	995	1,630,000
Total	40,300	38,100	56,400,000
Total silicon metal	81,800	78,800	214,000,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Contains 4,130 tons of material with silicon content not yet verified.
3/ Silicon content of material not yet verified.
4/ Less than ½ unit.
5/ Contains 220 tons of material with silicon content not yet verified.
6/ Contains 540 tons of material with silicon content not yet verified.
7/ Contains 125 tons of material with silicon content not yet verified.
8/ Contains 1,230 tons of material with silicon content not yet verified.
9/ Contains 398 tons of material with silicon content not yet verified.

Source: Bureau of the Census.

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SILVER

By Henry E. Hilliard

In 1996, domestic mine production of silver increased for the second consecutive year. The United States remained the third largest mine producer of silver, accounting for 10% of world mine output. About 76 mines in 16 States produced silver during the year. In descending order, Nevada, Idaho, and Arizona, were the largest silver-producing States, accounting for nearly two-thirds of the production. The 14 largest mines accounted for more than three-fourths of domestic production. The value of domestic production was $263 million.

Commercial-grade silver is a material that is at least 99.9%-pure silver. In the United States, about 20 companies produced commercial-grade silver from either primary or recycled material. Although most of these companies were headquartered in the Northeast, many had collection sites or plants in locations throughout the country. Aiding in the recycling of silver were many other companies. These companies, located throughout the country, collected the material for recycling, and some produced a semirefined product that could be converted to commercial-grade silver.

Many companies and probably thousands of artisans scattered throughout the country consumed silver in 1996. The 30 largest companies probably accounted for more than 90% of the silver consumed in arts and industry. About 50% of the commercial-grade silver consumed in the United States was used in the manufacture of photographic products; 20% in electrical and electronic products; 10% in electroplated ware, sterlingware, and jewelry; and 20% in other uses.

Analysts estimated that world fabrication demand for silver increased slightly in 1996, owing primarily to increased consumption in India and Mexico. Total world fabrication demand, including that of China and the former U.S.S.R., was put at about 25,000 tons in 1996, compared with a revised estimate of 23,900 tons in 1995 (The Silver Institute, 1997).

Production

Silver was produced from precious-metal ores at 46 lode mines and from base metal ores at 30 lode mines. In 1996, 14 mines each produced more than 30 tons of silver; their aggregated production equaled 79% of total domestic production. Probably fewer than 10 placer operations recovered silver in 1996, and the quantity recovered was less than 1% of total domestic production.

Domestic mine production data for silver were developed by the U.S. Geological Survey from three separate, voluntary surveys of U.S. operations. Typical of these surveys was the lode mine production survey of copper, gold, lead, silver, and zinc. Of the 78 silver-producing lode mines to which a survey form was sent, 76 responded, accounting for an estimated 99% of the total U.S. mine production shown in tables 1, 2, and 6.

Alaska.—The Greens Creek silver-zinc-lead-gold mine resumed mining in July. For the year, workers at Greens Creek milled nearly 131,000 tons of ore and recovered nearly 87 tons of silver, 11,600 tons of zinc, 5,200 tons of lead, and 323 kilograms of gold, (Hecla Mining Co., 1997). The mine had closed in April 1993, reportedly in response to low silver prices.

At the Red Dog Mine, Cominco Alaska Inc. began construction of a number of projects expected to result in a 40% increase in production capacity by 1998. The project will require construction of a new crushing plant, semiautogenous grinding and ball mills, additional filtering and flotation capacity, and expansion of the port facilities on the Chukchi Sea. Improved operations at the concentrator resulted in higher recoveries for lead, silver, and zinc.

Idaho.—Production resumed at the Coeur Mine in May. The Coeur Mine, an underground silver-copper-gold mine, was placed on standby in April 1991 in response to low silver prices. For the second half of 1996, Coeur milled nearly 142,000 tons of ore and recovered nearly 1,300 tons of copper and 88 tons of silver (Coeur d'Alene Mines Corp., 1997).

Silver production at the Kinross-DeLamar Mine declined in 1996, reportedly owing in part to lower than expected ore grades, unscheduled mill repairs, and severe weather conditions. For the year, workers at DeLamar processed nearly 1.3 million tons of ore and recovered nearly 37 tons of silver and more than 1 ton of gold (Kinross Gold Corp., 1997). In 1995, the mine had produced more than 56 tons of silver and 819 kilograms of gold.

Production at the Lucky Friday Mine increased in 1996. Company officials attributed the higher production in part to the use of jumbo platform drills as part of the continuing effort to mechanize the mine. During 1996, Hecla Mining Co. milled more than 171,000 tons of ore at Lucky Friday and recovered 29 kilograms of gold, 19,000 tons of lead, 59 tons of silver, and 3,300 tons of zinc. In 1995, workers at the mine had processed 144,000 tons of ore and recovered 26 kilograms of gold, 15,400 tons of lead, 52 tons of silver, and 2,720 tons of zinc (Hecla Mining Co., 1997).

Silver production at the Sunshine Mine increased for the first time in the past 6 years, and by yearend, the mine was operating at 75% of capacity (680 tons per day). For the year, the Sunshine Mine processed nearly 109,000 tons of ore and recovered 79 tons of silver, nearly 1,200 tons of lead, and 305 tons of copper (Sunshine Mining and Refining Co., 1997). The lead production reportedly was the first significant lead production at the mine in decades. In 1995, the Sunshine Mine

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had recovered nearly 54 tons of silver and 278 tons of copper from 91,600 tons of ore.

Montana.—Silver production at the Montana Tunnels Mine declined for the fourth consecutive year, despite the start of operations at Diamond Hill. Diamond Hill, a small underground operation, is a satellite deposit to the Montana Tunnels operation. As in 1995, the mill at Montana Tunnels processed more than 5 million tons of ore. Metal production for 1996 was approximately 3 tons of gold, nearly 29 tons of silver, 7,000 tons of lead, and 18,300 tons of zinc (Pegasus Gold Inc., 1997). For 1995, Montana Tunnels had milled more than 5 million tons of ore and recovered nearly 3 tons of gold, 33 tons of silver, 7,400 tons of lead, and 21,600 tons of zinc.

Nevada.—Although ore grades were lower than expected, increased mining activity resulted in significantly higher gold and silver production at the Candelaria Mine. For 1996, the mine produced 120 tons of silver and 468 kilograms of gold (Kinross Gold Corp., 1997). Corresponding production for 1995 was 88 tons and 331 kilograms of silver and gold respectively.

Both gold and silver production increased at the Denton-Rawhide Mine in 1996, owing in part to productivity gains. For the year, the heap-leach operation recovered more than 3,950 kilograms of gold and 33 tons of silver (Kinross Gold Corp., 1997). In 1995, the mine had produced 3,800 kilograms and 31 tons of gold and silver, respectively.

A project to expand the capacity of the mill serving the McCoy-Cove Mine was completed in April, enabling the mill to treat 6,800 tons of ore per day. Silver production at the McCoy-Cove Mine decreased significantly, owing primarily to the mining of lower grade ore. For 1996, the mine heap leached nearly 6 million tons of ore and recovered nearly 2,100 kilograms of gold and 16 tons of silver. Milling 3 million tons of ore produced an additional 6,370 kilograms of gold and 205 tons of silver (Echo Bay Mines Ltd., 1997). Corresponding data for 1995 were the heap leaching of 4 million tons yielding 1,860 kilograms and 27 tons of gold and silver, respectively, and the milling of 2.4 million tons yielding 7,780 kilograms of gold and 343 tons of silver.

Although gold production at the Rochester Mine increased during 1996, silver production declined slightly. The increased gold production was attributed in part to the completion of a new ore conveyor system in 1995 and to a decline in the waste-to-ore strip ratio in 1996. For the year, workers mined 7.3 million tons of ore and produced more than 2 tons of gold and 194 tons of silver (Coeur d'Alene Mines Corp., 1997). Corresponding data for 1995 included the mining of 7.5 million tons of ore and the production of nearly 2 tons and 202 tons of gold and silver, respectively.

Amax Gold Inc. completed mining operations at its Sleeper gold-silver mine during the first quarter. Although milling operations were terminated in August, residual heap leaching continued through yearend. Reclamation of the open pit site was under way by yearend and was expected to be completed by the year 2000.

World Review

Gold Fields Mineral Services Ltd. estimated that world fabrication demand for silver increased to nearly 25,000 tons in 1996, from 23,900 tons in 1995.

Mexico.—Continuing as the leading producer of silver, with 16% of world production, Mexico lifted ore containing 2,500 tons of silver from its mines in 1996, essentially unchanged from the revised output of 1995. More than 80% of Mexico's silver is usually produced by six States: Chihuahua, Durango, Guanajuato, Hidalgo, Sonora, and Zacatecas.

Most Mexican refined silver came from facilities that also refined lead and zinc. The Peñoles facility at Torreón, Coahuila, and the Grupo Mexico plant, in Chihuahua, refined lead concentrates and produced large quantities of silver in the process. Silver was also produced from zinc concentrates at both of these facilities. The Cobre de Mexico refineries in Mexico City and Celaya, Guanajuato, extracted silver electrolytically from copper anodes. Real del Monte, in Pachuca, has a precious metal refinery that processed silver and gold from the mine's own concentrates as well as from concentrates of other mines.

Peru.—With a silver production of 1,968 tons, Peru remained the world's second largest producer after Mexico. The state-owned corporation, Empresa Minera del Centro del Peru, led Peruvian silver producers in output, with 653 tons. Cía. de Minas Buenaventura S.A. and its subsidiary, Orcopampa, dominated the medium-sized silver-mining sector with more than 200 tons.

Outlook

Byproduct silver from the processing of other nonferrous metals such as copper, gold, lead, and zinc remains the dominant component of domestic and world silver supply. As a result, the quantity of silver produced is in many instances more dependent on the price of the principal metal mined than on the price of silver. Although domestic silver production will continue to respond to price movements for other nonferrous metals, it is believed that domestic production of silver will increase slightly in the near term, but remain in the range of 1,400 to 2,000 tons. Worldwide, mine production of silver should remain at about 15,000 tons.

During the next few years, the domestic demand for silver will likely follow the general economy, either upward or downward, but remain at approximately 3,700 tons. Similarly, local economic conditions are expected to be the major determinant of silver demand in other countries, although demand could increase slightly as new markets in less-developed countries are gradually developed.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT SILVER STATISTICS 1/

		1992	1993	1994	1995	1996
United States:						
Mine production	metric tons	1,800	1,640	1,490	1,560 r/	1,570
Value	thousands	$229,000	$227,000	$253,000	$259,000 r/	$263,000
Refinery production:						
Domestic and foreign ores and concentrates	metric tons	2,160	1,790	1,810	(2/)	(2/)
Scrap (old and new)	do.	1,760	2,020	1,700	(2/)	(2/)
Exports: Refined	do.	911	705	868	2,810	2,900
Imports for consumption: Refined	do.	2,660	2,180	2,060	2,630	2,580
Stocks, Dec. 31:						
Industry	do.	677	735	929	(2/)	(2/)
Futures exchanges	do.	9,380	10,500	10,400	6,290	4,550
Department of the Treasury	do.	775	NA	NA	NA	NA
Department of Defense	do.	29	34	15	13	NA
National Defense Stockpile	do.	2,260	1,850	1,670	1,450	1,450
Coinage	do.	NA	NA	NA	NA	NA
Price, average per troy ounce 3/		$3.94	$4.30	$5.29	$5.15	$5.19
Employment 4/		1,600	1,100	1,000	1,200	1,400
World: Mine production	metric tons	14,900 r/	14,400 r/	14,200 r/	15,100 r/	15,200 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits, except prices.

2/ Data under review.

3/ Price data are from Platt's Metals Week Annual Handy & Harman quotation.

4/ Employment data are from Mine Safety and Health Administration.

TABLE 2
MINE PRODUCTION OF SILVER IN THE UNITED STATES, BY STATE 1/

(Kilograms)

State	1995	1996
Alaska	109,000	W
Arizona	220,000	188,000
California	13,600 r/	21,600
Colorado	W	7,430
Idaho	182,000	229,000
Montana	76,700 r/	W
Nevada	693,000 r/	605,000
New Mexico	19,900	W
South Dakota	4,030	4,890
Other States 2/	247,000	517,000
Total	1,560,000 r/	1,570,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other States."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes Illinois, Michigan, Missouri, New York, South Carolina, Tennessee, Utah, Wisconsin, and States indicated by symbol "W."

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TABLE 3

TWENTY-FIVE LEADING SILVER-PRODUCING MINES IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of silver
1	McCoy - Cove	Lander, NV	Echo Bay Mines	Gold ore.
2	Rochester	Pershing, NV	Coeur Rochester Inc.	Do.
3	Bingham Canyon	Salt Lake, UT	Kennecott-Utah Copper Co.	Copper ore.
4	Red Dog	NW Arctic, AK	Cominco Alaska Inc.	Lead-zinc ore.
5	Candelaria	Mineral, NV	Kinross Delamar Mining Co.	Gold ore.
6	Greens Creek	Southeastern Alaska, AK	Kennecott Minerals Co.	Zinc ore.
7	Sunshine	Shoshone, ID	Sunshine Mining and Refining Co.	Silver ore.
8	Mission Unit 1/	Pima, AZ	ASARCO Incorporated	Copper ore.
9	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Lead-zinc ore.
10	Coeur	do.	ASARCO Incorporated	Silver ore.
11	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper ore.
12	Montana Tunnels	Jefferson, MT	Pegasus Gold Inc.	Zinc ore.
13	Denton-Rawhide	Mineral, NV	Kennecott Rawhide Mining Co.	Gold ore.
14	Kinross Delamar	Owyhee, ID	Kinross Delamar Mining Co.	Do.
15	Continental	Silver Bow, MT	Montana Resources Inc.	Copper ore.
16	Sierrita	Pima, AZ	Cyprus Minerals Co.	Do.
17	Bagdad	Yavapai, AZ	do.	Do.
18	Flambeau	Rusk, WI	Kennecott Corp.	Do.
19	Ray Unit	Pinal, AZ	ASARCO Incorporated	Do.
20	Robinson	White Pine, NV	BHP Copper	Do.
21	San Manuel	Pinal, AZ	do.	Do.
22	Casteel 2/	Iron, MO	The Doe Run Co.	Lead-zinc ore.
23	Buick	do.	do.	Do.
24	Chino	Grant, NM	Phelps Dodge Corp.	Copper ore.
25	Grouse Creek	Custer, ID	Hecla Mining Co.	Gold ore.

1/ Includes Eisenhower, Mission, Pima, and San Xavier Mines.

2/ Includes Brushy Creek Mill.

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TABLE 4
U.S. EXPORTS OF SILVER, BY COUNTRY 1/ 2/

Year and country	Ore and concentrates 3/		Dore and precipitates		Refined bullion		Total		Waste and scrap	
	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, gross weight)	Value (thousands)
1995	741	$233	72,100	$23,500	2,810,000	$497,000	2,890,000	$521,000	1,580,000	$304,000
1996:										
Belgium	--	--	--	--	141,000	28,300	141,000	28,300	243,000	39,700
Brazil	--	--	356	82	--	--	356	82	--	--
Canada	211	38	31	5	15,200	2,530	15,400	2,570	469,000	62,200
China	5	3	16	3	--	--	21	6	87,400	12,000
Denmark	--	--	--	--	49,800	19,500	49,800	19,500	36	5
France	250	45	--	--	--	--	250	45	39,200	6,870
Germany	--	--	3	6	61	11	64	17	59,700	16,400
Hong Kong	34	6	--	--	20,100	3,280	20,100	3,290	2,890	382
India	--	--	--	--	41	5	41	5	773	101
Israel	710	128	--		--	--	710	128	337	48
Italy	--	--	--	--	143	20	143	20	785	125
Japan	--	--	18,300	3,230	145,000	24,500	163,000	27,800	166,000	23,400
Korea, Republic of	--	--	--	--	11,900	2,120	11,900	2,120	188	38
Romania	--	--	--	--	--	--	--	--	163	21
Singapore	--	--	--	--	112,000	18,400	112,000	18,400	--	--
Sweden	--	--	--	--	--	--	--	--	39,200	6,950
Switzerland	--	--	8,650	1,610	750,000	136,000	758,000	138,000	487	1,910
Taiwan	--	--	13,100	2,560	9,710	2,130	22,800	4,690	2,160	442
Thailand	240	84	--	--	34,800	6,380	35,000	6,460	--	--
United Arab Emirates	--	--	--	--	493,000	87,500	493,000	87,500	--	--
United Kingdom	55	9	2,740	520	1,100,000	200,000	1,100,000	201,000	164,000	64,900
Uruguay	--	--	--	--	19,400	4,330	19,400	4,330	--	--
Other	17	3	113	15	1,230	225	1,360	243	1,040	716
Total	1,520	316	43,300	8,030	2,900,000	536,000	2,950,000	544,000	1,280,000	236,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary silver excluded.
3/ Includes base metal ores, concentrates, and matte imported for refining.

Source: Bureau of the Census.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY 1/ 2/

Year and country	Ore and concentrates 3/		Dore and precipitates		Refined bullion		Total		Waste and scrap	
	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, contained silver)	Value (thousands)	Quantity (kilograms, gross weight)	Value (thousands)
1995	225,000	$37,400	395,000	$124,000	2,630,000	$428,000	3,250,000	$590,000	2,140,000	$55,000
1996:										
Argentina	--	--	--	--	--	--	--	--	45	66
Australia	--	--	--	--	--	--	--	--	22,500	554
Brazil	--	--	--	--	5,530	1,100	5,530	1,100	68	179
Canada	7,970	1,050	50,100	9,040	1,100,000	188,000	1,160,000	198,000	243,000	10,100
Chile	--	--	202,000	78,300	58,300	9,840	260,000	88,200	1,780	1,090
Colombia	--	--	1,480	248	--	--	1,480	248	--	--
Costa Rica	--	--	247	37	--	--	247	37	--	--
Denmark	--	--	--	--	--	--	--	--	15,000	49
Dominican Republic	--	--	2,720	4,330	73,500	16,600	76,200	20,900	2,960	1,580
El Salvador	--	--	--	--	--	--	--	--	6,850	156
Estonia	--	--	--	--	--	--	--	--	778	2,870
France	--	--	--	--	--	--	--	--	7,780	1,750
Germany	--	--	(4/)	8	--	--	(4/)	8	566,000	3,170
Ireland	--	--	--	--	--	--	--	--	236	1,680
Israel	--	--	--	--	--	--	--	--	6,910	456
Italy	--	--	--	--	--	--	--	--	8,930	279
Japan	--	--	--	--	--	--	--	--	18,000	702
Malaysia	--	--	--	--	--	--	--	--	290,000	15,500
Mexico	145,000	24,400	5,670	938	942,000	156,000	1,090,000	182,000	17,200	5,950
Netherlands	--	--	--	--	--	--	--	--	116,000	517
Nicaragua	--	--	590	100	--	--	590	100	--	--
Panama	--	--	117	19	415	57	532	76	133	20
Peru	--	--	17,700	3,020	378,000	66,100	396,000	69,200	--	--
Philippines	--	--	--	--	--	--	--	--	74,300	1,220
Poland	--	--	--	--	16,000	2,750	16,000	2,750	--	--
Portugal	--	--	--	--	--	--	--	--	21,000	48
Russia	--	--	--	--	93	16	93	16	714	303
Singapore	--	--	--	--	--	--	--	--	6,380	117
South Africa	--	--	165	30	52	8	217	38	39	118
Switzerland	--	--	--	--	729	117	729	117	3	12
Thailand	--	--	--	--	--	--	--	--	351	665
United Kingdom	--	--	8	3	788	67	796	70	381,000	2,150
Other	--	--	1,080	194	(4/)	5	1,080	199	1,130	1,130
Total	153,000	25,500	281,000	96,300	2,580,000	441,000	3,010,000	562,000	1,810,000	52,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary silver excluded.
3/ Includes base metal ores, concentrates, and matte imported for refining.
4/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 6
SILVER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria e/	4	4	4	3	4
Argentina	45	43	38 r/	48 r/	48
Australia	1,218	1,092	1,045	939 r/	1,020 3/
Austria	2	--	2 r/	2 r/	1
Bolivia	282	333	352	425 r/	380
Brazil 4/	162	108 r/	50 r/	50 r/	50
Bulgaria e/	35	35	30	35	35
Burma	5	2	6	4	4
Canada (shipments)	1,220	896	740	1,245 r/	1,228 p/
Chile	1,029	970	983	1,032	1,035
China e/	800 r/	840 r/	810 r/	910 r/	930
Colombia 5/	8	7	6	6	7 3/
Costa Rica e/	(6/)	(6/)	(6/) 3/	(6/)	(6/)
Croatia e/	1	1	1	--	--
Czech Republic e/ 7/	XX	1	(6/)	-- 3/	--
Czechoslovakia e/ 8/	6	XX	XX	XX	XX
Dominican Republic	15	1 e/	2 e/	21 r/	21
Ecuador e/	(6/)	(6/)	(6/)	(6/)	(6/)
Fiji	1	1	1	2	2
Finland 9/	27	29	26	27 e/	26
France	13	10	1	1	1
Germany e/	1 r/ 3/	-- r/	-- r/	-- r/	--
Ghana e/	2	2	2	3	3
Greece	62	59	45	33 r/	30
Honduras	43	24	25	25 e/	29 3/
India	47	51	50	38 r/	40
Indonesia	100	90	107	183 r/	185
Iran e/	50	60	60	60	60
Ireland	13	13	17	14 r/	14
Italy 10/	12	5	14	12 e/	12
Japan	178	137	133	100	85 3/
Kazakstan e/ 5/	500 r/	500 r/	500 r/	489 r/ 3/	480
Korea, North e/	50	50	50	50	50
Korea, Republic of 5/	333	215	257 r/	299 r/	254 3/
Macedonia e/	10	10	10	10	10
Malaysia	15	14	13	11	10 3/
Mali e/	(6/)	(6/)	(6/)	(6/)	(6/)
Mexico	2,098	2,420	2,330	2,496 r/	2,500
Morocco	213	309	328	330 e/	300
Namibia	89	72	62	66	42 3/
New Zealand	22	26	28 r/	28 r/	30
Nicaragua	2	2	2 e/	2 e/	2
Papua New Guinea	95	96	66 r/	65	59 3/
Peru	1,614	1,631	1,742	1,909 r/	1,968 3/
Philippines	33	28	30	27	20
Poland	798	767	1,064	1,001	1,100
Portugal	39	36	32	39 r/	38
Romania e/	73	70	70 3/	60	60
Russia e/	800	800	800	700	700
Saudi Arabia	16	18	17	18 e/	17
Serbia and Montenegro	66	25	18	31 r/	30
Slovenia e/	(6/)	--	--	--	--
Solomon Islands	(6/)	(6/) e/	--	--	--
South Africa	183	192	196	174	167 3/
Spain	206 r/	158 r/	136 r/	102 r/	100
Sweden	210	255	276	268	270
Tunisia e/	1	1	1	1	1
Turkey e/	103	103	65	65	65
United States	1,800	1,640	1,490	1,560 r/	1,570 3/
Uzbekistan e/	55	60	65	65	70
Zaire e/	18 r/	18 r/	12 r/	8 r/	10

See footnotes at end of table.

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TABLE 6--Continued
SILVER: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Zambia 11/	21	16	12 r/	8 r/	11
Zimbabwe	17	12	11	16 r/	16
Total	14,900 r/	14,400 r/	14,200 r/	15,100 r/	15,200

e/ Estimated. p/ Preliminary. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through June 13, 1997.

3/ Reported figure.

4/ Includes the following quantities, in kilograms, identified as secondary silver: 1992--21,170 (revised); 1993--42,500 (revised); 1994--30,000 (revised); 1995--35,000 (revised); and 1996--35,000 (estimated).

5/ Smelter and/or refinery production.

6/ Less than 1/2 unit.

7/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

8/ Dissolved Dec. 31, 1992.

9/ Metal content.

10/ Includes production from imported ores.

11/ Year beginning Apr. 1 of that stated.

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SLAG—IRON AND STEEL

By Rustu S. Kalyoncu

The diverse uses of iron and steel slags, coproducts of the iron and steel industry, range from construction and road building to waste stabilization. Slags are also used in cement manufacture, concrete aggregates, fill, glass manufacture, and in agriculture as soil amendment.

Slags are produced in many metallurgical operations. Iron and steel slags are produced during iron and steel manufacture. In the production of iron, the blast furnace is charged with iron ore, fluxing agents, usually limestone and dolomite, and coke as fuel. From this, molten slag and iron, are formed. Slag is produced typically at a rate of 220 to 370 kilograms per ton of pig iron. The slag is transported into a cooling pit, either directly or via iron ladles, as determined by its proximity to the furnace. The slag consists primarily of calcium, magnesium, and aluminum silicates in various combinations. Depending on the cooling method, three types of slag are produced, namely air-cooled, expanded, and granulated.

Air-cooled slag is produced by allowing the molten slag to cool in air in an open pit. The density and porosity of slag are affected by cooling rates and chemical composition. When the material solidifies under slow cooling conditions, escaping gases leave behind a porous, low- density aggregate with special physical properties, making it suitable for many applications. When formed under controlled rapid cooling (quenching), the slag tends to be hard and dense, making it especially suitable for use in road base and similar structural applications.

Expanded slag is formed through controlled rapid cooling of molten slag in water or in water with combination of steam and compressed air. Formation of steam and other gases enhance the porosity and vesicular nature of the slag resulting in a lightweight aggregate, suitable for use in concrete.

Granulated slag is produced by quenching (rapid cooling) the molten slag into glass by high-pressure water jets. Quenching prevents crystallization, thus resulting in a granular, glassy aggregate. This slag is crushed, pulverized, and screened for use in various applications, particularly in cement production, because if its pozzolanic characteristics.

Slags are also coproducts of steelmaking processes. Production of steel calls for the removal of excess silicon and carbon from iron by oxidation. Steel slag is a hard, dense material somewhat similar to air-cooled iron slag. It contains significant amounts of free iron, giving it its high density and hardness. Hardness and high density make it particularly suitable as road construction aggregate.

Legislation and Government Programs

Classification of slags under several standard waste categories has been the subject of a number of governmental initiatives. Legislatively, 1996 was relatively a quiet year. According to the National Slag Association, no known major government action was recorded.

Production

Actual ferrous slag production data in the United States do not exist as the iron and steel industry does not routinely measure slag output. Consequently, the data collected by the U.S. Geological Survey (USGS) are only of the slag industry quarry sales. Slag outputs in iron and steel production are highly variable and largely depend, for the most part, on the feed chemistry and the type of furnace. Typically, for an ore feed of 60% to 66% iron, blast furnace slag production ranges from about 220 to 370 kilograms per metric ton of pig iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as 1 ton of slag per ton of pig iron. Steel slag output is typically 20% by mass of the steel output. About half of this amount is entrained steel, which generally is recovered and returned to the furnace. The marketable slag after removal of the entrained steel makes up about 10 to 15% of the steel output. According to statistics reported by International Iron and Steel Institute (IISI), the U.S. pig iron production is about 50.9 million and 49.6 million tons in 1995 and 1996 respectively. Thus, the iron slag production for these years would range from 12 million to 13 million tons each. Likewise, U.S. steel production for 1995 and 1996 was reported to be 95.2 and 95 million tons respectively. This puts the expected steel slag production figures in the range from 10 million to 15 million tons.

As with the United States, there are no data on world slag production. The IISI reported world's pig iron output in 1996 to be about 512 million tons and crude steel production to be 752 million tons. Estimated ferrous slag production figure from these numbers would be approximately 250 million tons.

Tables 1 through 7 present data compiled by surveying the domestic slag producers. The data for 1995 reflect a response by all 17 companies queried and that for 1996 a response by 16 operations. Where applicable, estimates have been incorporated for data omitted from the returned questionnaires.

Table 8 lists the production facilities that responded to the survey in 1996. One minor company ceased operations, three plants closed, and seven plants from various companies did not produce any slag. International Mill Service purchased Alexander Mill Service and Koch Minerals plant was bought by Holnam Mill Service. The largest slag processor was International Mill Service with 45 plants.

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Consumption

The correlation between slag production and availability is not a good indicator of consumption trends time lag between production and sale of the slag to the final customer can be significant. The primary reason for the lag is the necessity for aging the new slag to reduce its free- lime content for certain applications, such as concrete production. High levels of free-lime can adversely affect concrete performance. Generally, slag will be stored to "cure" for 6 months or longer to bring the free-lime content to acceptable levels. Furthermore, slag producers seek to keep large stockpiles to be able to participate in bids for large projects.

Air-cooled slag makes up the bulk of slag production in the United States. The total U.S. sales of about 12.2 million tons, worth $67.5 million in 1996, of domestically produced air-cooled blast furnace slags recorded a slight increase of little more than 1%, over the sales in 1995, as shown in table 1. The slight increase in production was more than offset by the decrease in price. There was 7% decrease in the expanded plus granulated slag sales from those of 1995. As shown in table 2, however, the overall decrease was somewhat offset by slightly higher prices. Total revenues of $141 million for 1996 were about 2% lower than those of 1995. As shown in table 3, the North Central region remained the leader in sales of blast furnace slags, accounting for more than 50% of tonnage and about half the revenues for the whole country.

Table 4 lists the major use of air-cooled blast furnace slags in the United States. Continued to be as aggregate for concrete and road construction. Other uses of slag were in roofing, soil conditioning, sewage treatment and mineral wool production.

Table 5 lists the 1995 and 1996 use statistics for steel slag sales. Road base was the primary use followed by construction aggregates and others making up the remaining uses. The 7% decline in production from 7.1 million tons in 1995 to 6.6 million tons in 1996 translates into a 5% decline in revenues.

Transportation

As shown in table 7, the bulk of the slag was transported by truck; rail and barge transportation accounting for only about 10% of the total. Relatively short destinations, seldom exceeding 75 kilometers, make the use of trucks the preferred means of transportation.

Current Research and Technology

Recently, there has been some improvements in slag granulation systems, especially in reducing the energy costs. A granulator with a variable-speed rotating cup atomizer to break up the molten slag by centrifugal force and to distribute it within a water-cooled cylindrical chamber has been developed (Macauley, 1996). The process cools the molten slag rapidly enough to create small granules, thus minimizing the need for additional crushing and grinding. It also has the advantage of reducing the pollution associated with wet granulation as the absence of water prevents the formation of hydrogen sulfide and sulfur oxides, other than a limited quantity of sulfur dioxide emitted from the liquid slag. Moreover, the new system offers the possibility of considerable energy recovery in the form of hot water or the heated air.

Outlook

Potential classification by the U.S. Environmental Protection Agency of iron and steel slags as hazardous wastes is of constant concern to the slag industry. Otherwise, owing to its physical properties and relatively high chemical inertness, ferrous slag has a secure future in the construction industry. However, some slag plants have been closing owing to inability to compete in the market place. In the case of continuing plant closings, availability of domestic blast furnace slag may decline. This may necessitate an increase in imports. With its more limited uses, the long term-supply of steel slag appears to be more stable. We may see an increase in the use of steel slags as the blast furnace slag production experiences decline.

If a carbon tax is levied on coal consumers, the cement industry, as a coal user, may be encouraged to increase the production of blended cements in order to lower fuel consumption. This may lead to increased use of slags by the cement industry.

Reference Cited

Macauley, D., 1996, Slag Treatment - Time for an Improvement: Steel Times/Steel Times International, September, p. S15-S16.

SOURCE OF INFORMATION

National Slag Association.

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TABLE 1
IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES 1/ 2/

(Thousand metric tons and thousand dollars)

	Blast furnace slag									
	Air-cooled		Expanded 3/		Total		Steel slag		Total slag	
Year	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/	Quantity	Value 4/
1995	12,000	68,200	1,810	53,700	13,800	122,000	7,160	22,600	21,000	144,000
1996	12,200	67,500	1,680	52,400	13,900	120,000	6,640	21,500	20,500	141,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes imported slag.
3/ Includes granulated slag to avoid disclosing company proprietary data.
4/ Value is the selling price at plant and includes, for a few facilities, estimates reported by the plants and/or made by the U.S. Geological Survey.

TABLE 2
AVERAGE VALUE AT THE PLANT FOR IRON AND STEEL SLAG SOLD
OR USED IN THE UNITED STATES, BY TYPE

(Dollars per metric ton)

	Iron blast furnace slag				
Year	Air-cooled	Expanded 1/	Total iron slag	Steel slag	Total slag
1995	5.68	29.73	8.82	3.16	6.89
1996	5.55	31.21	8.66	3.24	6.90

1/ Includes granulated slag to avoid disclosing company proprietary data.

TABLE 3
BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY REGION AND STATE 1/ 2/

(Thousand metric tons and thousand dollars)

	1995				1996			
	Air-cooled		Total, all types		Air-cooled		Total, all types	
Region and State	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
North Central: Illinois, Indiana, Michigan, Ohio	7,960	44,300	8,800	60,100	7,800	43,900	8,550	59,500
Middle Atlantic: Maryland, New York, Pennsylvania, West Virginia	2,200	15,100	3,160	52,900	2,170	15,100	3,090	51,900
Other 4/	1,860	8,860	1,860	8,860	2,210	8,560	2,210	8,560
Total	12,000	68,200	13,800	122,000	12,200	67,500	13,900	120,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes imported slag.
3/ Value based on selling price at plant.
4/ Includes Alabama, California, Kentucky, and Utah.

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TABLE 4
AIR-COOLED BLAST FURNACE SLAG SOLD
OR USED IN THE UNITED STATES, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Asphaltic concrete aggregate	1,920	11,700	2,180	12,700
Concrete aggregate	1,140	8,360	1,390	10,000
Concrete products	327	2,190	342	2,390
Fill	1,340	4,010	1,730	6,520
Glass manufacture	W	W	W	W
Mineral wool	647	4,420	653	4,630
Railroad ballast	108	569	123	628
Road bases	5,470	30,700	4,820	24,300
Roofing, built-up and shingles	63	589	59	647
Sewage treatment	W	W	W	W
Soil conditioning	W	W	W	W
Other 3/	997	5,650	881	5,700
Total	12,000	68,200	12,200	67,500

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown. Excludes imports.
2/ Value based on selling price at plant.
3/ Includes cement, ice control, miscellaneous, and uses indicated by symbol "W."

TABLE 5
STEEL SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars)

Use	1995		1996	
	Quantity	Value 3/	Quantity	Value 3/
Asphaltic concrete aggregate	1,040	4,800	1,000	4,170
Fill	1,380	3,660	1,330	3,330
Railroad ballast	168	553	182	534
Road bases	2,820	7,940	2,430	8,500
Other 4/	1,760	5,630	1,700	5,020
Total	7,160	22,600	6,640	21,500

1/ Data are rounded to three significant digits; may not add to totals shown. Excludes imports.
2/ Excludes tonnage returned to furnace for charge material.
3/ Value based on selling price at plant.
4/ Includes ice control, soil conditioning, and miscellaneous uses.

TABLE 6
AVERAGE AND RANGE OF SELLING PRICES AT THE PLANT FOR IRON AND STEEL
SLAG IN THE UNITED STATES IN 1996, BY USE

(Dollars per metric ton)

Use	Iron blast furnace slag 1/		Steel slag	
	Average	Range	Average	Range
Asphaltic concrete aggregate	5.83	3.99 - 11.81	4.16	2.03 - 6.69
Cement manufacture	W	W	W	W
Concrete products	6.98	W	(2/)	(2/)
Fill	3.71	.38 - 7.07	2.51	1.30 - 4.27
Glass manufacture	W	W	W	W
Mineral wool	7.08	2.79 - 9.04	W	(2/)
Railroad ballast	5.15	3.92 - 7.96	3.49	1.90 - 3.00
Road bases	5.00	.27 - 8.60	2.93	1.05 - 4.42
Roofing, built-up and shingles	10.97	5.50 - 15.00	(2/)	(2/)
Sewage treatment	W	W	W	W
Soil conditioning	W	W	W	W
Other	5.65	2.15 - 15.00	2.96	.33 - 16.46

W Withheld to avoid disclosing company proprietary data.
1/ Air-cooled slag only. Price range breakouts, by use, for granulated and expanded slag are withheld to avoid disclosing proprietary information; overall, prices ranged from $3.00 to $50.00 per ton.
2/ No use reported.

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TABLE 7
SHIPMENTS OF IRON AND STEEL SLAG IN THE UNITED STATES
IN 1996, BY METHOD OF TRANSPORTATION 1/ 2/

Method of transportation	Quantity (thousand metric tons)
Truck	16,500
Rail	1,000
Waterway	1,010
Total transported	18,600
Not transported (used at plant)	1,950

1/ Data are rounded to three significant digits; may not add to total shown.
2/ Excludes imported slag.

TABLE 8
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 1996

		Steel slag			Iron slag	
Company	Plant location	Basic oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Slag type
American Aggregates	Dayton, OH	X				Air-cooled.
Blue Circle Atlantic Inc.	Sparrows Point, MD				X	Granulated.
Buffalo Crushed Stone	Buffalo, NY	X				Air-cooled.
C. J. Langenfelder	Baltimore, MD	X				--
Do.	Braddock, PA	X				--
Heckett MultiServ Co.	Hickman, AR			X		--
Do.	Fontana, CA				X	Air-cooled.
Do.	Wilton, IA			X		--
Do.	Chicago, IL				X	Air-cooled.
Do.	Cook, IL			X		--
Do.	Riverdale, IL			X		--
Do.	Sterling, IL			X		--
Do.	East Chicago, IN	X				--
Do.	Indiana Harbor, IN	X				--
Do.	Ashland, KY	X			X	Air-cooled.
Do.	Coalton, KY			X		--
Do.	Newport, KY			X		--
Do.	Owensboro, KY			X		--
Do.	Kansas City, MO			X		--
Do.	Mansfield, OH	X				--
Do. (Warren Plant)	Warren, OH	X				--
Do.	do.			X		--
Do.	Youngstown, OH			X		--
Do.	Butler, PA			X		--
Do.	Provo, UT		X		X	Air-cooled.
Do.	Seattle, WA			X		--
International Mill Service	Fort Smith, AR			X		--
Do.	Kingman, AZ			X		--
Do.	Pueblo, CO	X				--
Do.	Claymont, DE			X		--
Do.	New Castle, DE			X		--
Do.	Tampa, FL			X		--
Do.	Bartow, GA			X		--
Do.	Cartersville, GA			X		--
Do.	Alton, IL			X		--
Do.	Bourbonnais, IL			X		--
Do.	Chicago, IL			X	X	Air-cooled.
Do.	Granite City, IL	X				--
Do.	Gary, IN			X		--
Do.	Huntington, IN			X		--
Do.	Laplace, LA			X		--
Do.	Jackson, MI			X		--
Do.	Monroe, MI			X		--
Do.	St. Paul, MN			X		--
Do.	Charlotte, NC			X		--
Do.	Perth Amboy, NJ			X		--
Do.	Riverton, NJ			X		--

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TABLE 8--Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 1996

Company	Plant location	Steel slag			Iron slag	
		Basic oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Slag type
International Mill Service--Continued:	Marion, OH			X		--
Do.	Middletown, OH	X		X		--
Do.	Mingo Junction, OH	X		X		--
Do.	Sand Springs, OK			X		--
Do.	McMinnville, OR			X		--
Do.	Portland, OR			X		--
Do.	Beaver Falls, PA			X		--
Do.	Coatesville, PA			X		--
Do.	Holsopple, PA			X		--
Do.	Midland, PA			X		--
Do.	Pricedale, PA	X		X		--
Do.	Reading, PA	X		X		--
Do.	Cayce, SC	X		X		--
Do.	Georgetown, SC	X		X		--
Do.	Jackson, TN	X		X		--
Do.	Beaumont, TX	X		X		--
Do.	El Paso, TX	X		X		--
Do.	Jewett, TX	X		X		--
Do.	Longview, TX	X		X		--
Do.	Midlothian, TX	X		X		--
Do.	Sequin, TX	X		X		--
Do.	Plymouth, UT	X		X		--
Do.	Saukville, WI	X		X		--
Koch Minerals	Gary, IN				X	--
Do.	Weirton, WV				X	--
Lafarge Corp.	Madison, IL				X	Air-cooled.
Do.	Cleveland, OH				X	Air-cooled and expanded.
Do.	Cuyahoga, OH				X	--
Do.	Jefferson, OH				X	--
Do.	Lordstown, OH		X			Granulated.
Do.	McDonald, OH		X			--
Do.	Mingo Junction, OH				X	Air-cooled.
Do.	Trumbull, OH				X	--
Do.	Warren, OH				X	Air-cooled.
Do.	Youngstown, OH		X			--
Do. (Brown Reserve)	Allegheny, PA				X	--
Do.	do.				X	--
Do.	Beaver, PA				X	--
Do.	West Aliquippa, PA				X	--
Do.	West Mifflin, PA				X	Air-cooled.
Do. (Duquesne)	do.	X	X		X	Do.
Do.	Brooke, WV				X	--
Do.	do.				X	--
Do.	Weirton, WV				X	Air-cooled.
Edward C. Levy Co.	Detroit, MI	X		X	X	Air-cooled and expanded.
The Levy Co. Inc.	Burns Harbor, IN	X			X	Air-cooled.
Do.	East Chicago, IN				X	Do.
Maryland Slag Co.	Sparrows Point, MD				X	Do.
Stein, Inc.	Cleveland, OH	X				--
Do.	Lorain, OH	X			X	Air-cooled.
United Slag Co.	Rancho Cucamonga, CA			X		--
Vulcan	Alabama City, AL				X	Air-cooled.
Do.	Fairfield, AL	X			X	Do.
Waylite Corp.	Bethlehem, PA	X	X		X	Air-cooled and expanded.

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SODA ASH

By Dennis S. Kostick

Soda ash, also known as sodium carbonate, is an inorganic chemical that is produced from the mineral trona or sodium carbonate-bearing brines, or from the reaction of primarily salt and limestone in a chemical reaction. This commodity is used in many familiar household products, such as glass, soaps and detergents, paper, textiles, and foods. The United States has the world's largest deposit of trona and represents about one-third of total world soda ash output.

Because soda ash is used in flat glass for automobile manufacture and building construction, which are important economic sectors of the domestic economy, monthly soda ash production data are incorporated into monthly economic indicators for industrial production by the Federal Reserve Board that monitor the economic condition of the U.S. economy. Soda ash and the various consumer products it is incorporated into, contribute substantially to the gross domestic product of the United States.

Production

Monthly soda ash production and inventory data are collected by the U.S. Geological Survey (USGS) from monthly, quarterly, and annual voluntary surveys of the U.S. soda ash industry. Of the six soda ash operations to which a survey request was sent, all responded, representing 100% of the total production data shown in this report. *(See table 1.)*

The U.S. soda ash industry in 1996 was composed of six companies; five in Wyoming produced soda ash from underground trona ore and one in California produced soda ash from sodium carbonate-rich brines. Many foreign synthetic soda ash producers have now become advocates of having a presence in the U.S. natural soda ash industry. Foreign investment in U.S. soda ash operations has risen from 10% of capacity in 1981, when Société Nationale Elf Aquitaine of France bought Texasgulf Chemical Co., to 51% in 1996. All of the six U.S. companies have either Australian, Belgian, French, South Korean, or Japanese partners. Since the beginning of the European producers' acquisitions of or partnerships in some of the U.S. facilities (Société Nationale Elf Aquitaine of France owning 100% of Tg Soda Ash and Solvay S.A. of Belgium owning 80% of Solvay Minerals Co.), the international competitive situation had begun to change. Approximately 24% of the Wyoming soda ash production capacity is European-owned as of 1996 (Tg Soda Ash with 1.18 million metric tons and Solvay with 1.67 million tons); a decline from 35% in 1995 when Rhône-Poulenc S.A. of France sold its Wyoming soda ash facility to Oriental Chemical Industries of the Republic of Korea.

The capacity expansion project between FMC Wyoming Corp. and its partners Nippon Sheet Glass Co., Ltd. and Sumitomo Corp., both of Japan, came on-stream in May that added 635,000 tons (700,000 short tons) of capacity to FMC's existing 2.59 million tons (2.85 million short tons) of capacity (Industrial Minerals, 1996a). The new process takes spent mine tailings in a slurry of soda liquors, which normally were discharged to surface tailing ponds, and injects them underground where the solutions migrate downslope to a natural depression in the mine that acts as a collection sump. The solution becomes enriched in sodium carbonate as it dissolves trona in the floor and pillars in abandoned sections of the mine. The solution is recovered and pumped to the surface and becomes feedstock for the soda ash refinery. The process reportedly will reduce production costs by 30% to 40%. Approximately 210,000 tons of soda ash from the new expansion was schedule to be used in FMC's project with DuPont. Iron chloride and hydrochloric acid wastes at DuPont's New Johnsonville, TN, titanium dioxide plant were to be treated with soda ash to produce iron carbonate and about 200,000 tons of food-grade salt, which will be marketed by North American Salt Co. The project was to come on-stream in mid-1996; however, the startup was delayed because of "normal startup issues," according to company officials. (Chemical Market Reporter, 1996a).

After Solvay Minerals Inc., brought on-stream its 272,000-ton expansion in late 1995, it announced a three-phase $170 million project to add another 1.09 million tons of capacity beginning in 1999 with the third phase to be finished by 2003 (Chemical Market Reporter, 1996b). This would increase its present annual nameplate capacity from 2.09 million tons to 3.18 million tons, making Solvay the second-largest soda ash facility in Wyoming after FMC. Part of Solvay's new capacity will be to replace that lost because of closure of the synthetic soda ash plant in Chiba, Japan, by its joint-venture partner, Asahi Glass Co. The Chiba facility was scheduled to shut down by September 1997.

In early 1996, Rhône-Poulenc S.A. of France sold its U.S. affiliate, Rhône-Poulenc Basic Chemicals Co., for $150 million to Oriental Chemical Industries Co., Ltd., (OCI) of the Republic of Korea. The sale was for the 51% share of the Wyoming soda ash plant; the remaining 49% owned by Union Pacific Resources Co. was unaffected. The sale did not include Rhône-Poulenc's sodium bicarbonate business in Chicago Heights, IL. OCI, which also operates a synthetic soda ash plant in Inchon and has a reported 7% share in North American Chemical Co.'s Searles Lake operation, announced plans to raise capacity at its Wyoming facility by 725,000 tons to 907,000 tons (800,000 short tons to 1 million short tons) per year by 1998 (Chemical Market Reporter, 1996c). The cost of the expansion project

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was estimated at $150 million. Although it was not reported, the expansion may be replacement capacity if OCI decides to close its Inchon plant, which has an annual capacity of about 400,000 tons.

On November 21, 1996, Tg Soda Ash, Inc., announced the development of new process technology to produce soda ash from a solution-mined feedstock at its Granger, WY facility. The new technology will utilize dilute solutions from underground mine water and recycled liquors from the soda ash crystallizers. The solutions will collect in an underground mine "lake" for subsequent processing. The feedstock will be steam stripped in a new process to convert some of the sodium bicarbonate contained in the solution to sodium carbonate prior to crystallizing sodium carbonate decahydrate crystals. The process does not use any solvents such as caustic soda or other chemical agents to convert the sodium bicarbonate (The Rocket Miner, 1996).

U.S. production of natural soda ash from California and Wyoming in 1996 increased slightly to a record 10.2 million tons. Based on 12.07 million tons of total nameplate capacity, the U.S. soda ash industry operated at 85% of total nameplate capacity. Capacity utilization was lower in 1996 compared with that of 1995 because FMC's 635,000 tons of new expansion capacity that came on-stream in May was not fully utilized because of startup problems associated with DuPont's project that would have used about one-third of this quantity.

Cominco American Corp. and Vulcan Chemicals decided to sell Owens Lake Soda Ash Co., their joint-venture at Owens Lake in California. The company terminated plans to construct a 544,000-ton-per-year (600,000 short tons) soda ash facility in 1995 because of delays in obtaining an environmental permit. Several companies evaluated the assets of the project but no buyer was found by yearend (Industrial Minerals, 1996b).

North American Chemical Co.'s subsidiary, White River Nahcolite Minerals, announced plans on June 11 to expand its natural sodium bicarbonate facility near Rifle, CO, by 90,700 tons (100,000 short tons) (North American Minerals News, 1996). The present capacity is 96,200 tons (106,000 short tons). Another nahcolite company, AmerAlia Inc., completed core hole drilling at its Rock School Lease in the Piceance Creek Basin of Colorado. Three nearly horizontal beds of nahcolite were located having an average nahcolite content of 26.5% with a thickness of 510 feet at a depth of 2,020 feet. The company plans to construct a sodium bicarbonate plant by the fall of 1997 with an initial capacity of 45,400 tons (50,000 short tons) (Chemical Market Reporter, 1996d).

A total of 222,000 tons of soda ash equivalent was used to manufacture chemical caustic soda by FMC, Solvay Minerals, and Tg Soda Ash. The total quantity of trona mined in Wyoming in 1996 was 16.3 million tons. *(See table 7.)*

Legislation and Government Programs

Soda ash mined on Federal lands is subject to the Mineral Leasing Act of 1920, which provides royalty payments to the United States Government. In Wyoming, the trona deposit within the Known Sodium Leasing Area is under the jurisdiction of the U.S. Government (administered by the Bureau of Land Management [BLM]), the State, and the Union Pacific Railroad, which was given alternate 0.6-square-kilometer sections (1-square-mile) north and south of the railway it constructed in the 1860's. Of the almost 370,000 hectares (915,000 acres) of total sodium mineral estate, the Federal ownership is 55.7%, Union Pacific, 38.1%; and the State, 6.2%. Sixteen lessees hold 53 active and inactive Federal leases having a total of 75,783 acres. In order to prevent a possible land monopoly, no lessee may hold more than 6,216 hectares (15,360 acres) of Federal land, but may lease more private or State land. The State royalty rate is tied to the Federal rate, which was 5%; however, the private royalty rate varies. One-half of all Federal royalties collected by the Minerals Management Service is disbursed to the Wyoming Government for various State and local programs. A Federal lease is issued for an initial period of 20 years, with 10 year discretionary renewals thereafter.

On February 22, 1996, the Assistant Secretary-Land and Minerals of the U.S. Department of the Interior signed the policy that increased the Federal royalty rate from 5% to 6% for renewed leases and from 5% to 8% for new leases. This resulted in 5 Federal leases remaining at 5% until they are up for renewal, 49 leases at 6%, and 10 leases at 8%. The Federal royalty is based on the quantity of the output of the sodium compounds and other related products at the point of shipment to market. Each Federal lease also has other costs, such as bonds, acreage rental fees, sodium prospecting permit application fees, and permit bonds.

On May 1, 1996, three Federal tracts totaling 1,036 hectares (2,560 acres) that had 88.9 million tons (97.9 million short tons) of trona were offered for lease by the BLM. Two bids met or exceeded the presale estimate of fair market value and were accepted; the third was rejected because it failed to meet fair market value. On September 26, eight more tracts totaling 4,522 hectares (11,174 acres) containing 461 million tons (508 million short tons) were offered for lease. Six bids met or exceeded fair market value estimates and were accepted, generating $10.8 million in bonus bids, of which one-half goes to the State of Wyoming.

Consumption

The USGS collects reported consumption data by end use quarterly from the marketing and sales departments of each company within the industry. Every effort has been made to categorize company sales with the intended end-use sector. Quarterly reports are often revised in subsequent quarters because of customer reclassifications, or other factors. Because all six U.S. soda ash companies respond to the quarterly survey, the data represents 100% of the total reported consumption data found in this report. Reported consumption data and apparent consumption data do not necessarily correspond because reported consumption data are based on actual sales whereas apparent consumption data are the calculated quantity available for domestic consumption based on balancing supplies

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(production, imports, and inventory adjustments) with external demand (exports). *(See table 3.)*

U.S. apparent consumption and reported consumption in 1996 varied by only 80,000 tons. The discrepancy between the two forms of consumption was attributed to disagreement between the sources of export data used to derive consumption statistics. The two sources were the Bureau of the Census, which reports exports upon departure from the U.S. ports, and the soda ash producers, which consider a shipment as exported when their export association (ANSAC) takes consignment of the product at California or Wyoming plant sites. Transit times between the plant and port, which can take about 2 to 3 weeks before the cargo is actually exported, and carryover export inventories contribute to the discrepancy between reported and apparent consumption as well.

The distribution of soda ash by end use in 1996 was glass, 48%; chemicals, 27%; soap and detergents, 12%; distributors, 5%; pulp and paper, 3%; flue gas desulfurization and miscellaneous, 2% each, and water treatment, 1%.

Glass.—Glass manufacture represented about 48% of domestic soda ash consumption, with the container sector comprising 51%; flat, 33%; and specialty and fiber, 8% each. According to Bureau of the Census data, production of glass containers declined from 9.71 million tons (10.70 million short tons) in 1995 to 8.82 million tons (9.72 million short tons) in 1996, primarily because of the beverage sector which continued to decline because more soft drinks were packaged in plastic containers than glass bottles. Glass containers for the beer industry increased from 38% of total container glass in 1995 to 43% in 1996. Glass for the wine bottling industry rose from 10% to 12% during the same time period.

The glass recycling rate remained the same at about 37%, of which postconsumer cullet was estimated at 24% of this rate with the remainder being in-house scrap. Some municipalities have started to terminate glass collection programs because the price of clean, sorted cullet has declined, thereby making it less attractive to recyclers. Another reason is that breakage during collection has affected the quality of material sold to glass container manufacturers.

Based on Bureau of the Census data with between 11% to 19% of the data being estimated, flat glass production decreased about 1.5% which contradicts the 3% increase noted from the soda ash end-use survey. Guardian Industries Corp. brought on-stream a new float glass plant at Dewitt, IA, in 1996 that will increase flat glass production and soda ash consumption in the future. The demand for window glass for automobiles and residential and commercial building construction has been increasing since 1990.

Anchor Glass Container Corp., which had been the second largest glass container manufacturer in the United States, was offered for sale by Vitro S.A. of Mexico, its parent corporation. Vitro reportedly needed capital because of depressed economic conditions in Mexico and the sagging glass container market within the United States. Vitro filed for bankruptcy protection and was negotiating to sell its assets, which were listed at $1.2 billion with liabilities of $951 million, to Ball-Foster Glass Container Co. for $365 million and the transfer of certain liabilities (Industrial Minerals, 1996c).

Chemicals.—Soda ash is used to manufacture many sodium-base inorganic chemicals, including sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates. Part of the 2% increase in reported consumption of soda ash in the chemicals sector from 1995 to 1996 was because 222,000 tons of soda ash equivalent was consumed to produce liquid chemical caustic soda that was used in various downstream applications. Chemical caustic soda caters to certain Western markets that are fairly distant from electrolytic caustic soda plants. Although low-priced caustic soda has had a negative affect on soda ash sales, chemical caustic soda sales remain strong.

According to data from the Bureau of the Census, production of sodium bicarbonate increased from 418,000s ton in 1995 to 432,000 tons in 1996. The estimated end-use distribution for sodium bicarbonate consumption was household products, 30%; animal feed, 20%; food and beverages, 17%; chemicals, 12%; pharmaceuticals, 8%; fire extinguishers, 3%; and miscellaneous, 10%.

Sodium phosphates are another important sector of the chemical industry that uses soda ash. There are several sodium phosphate-bearing compounds; unfortunately, most of the data that are available are withheld by the Bureau of the Census because of the number of respondents required to publish statistics. However, an estimate of the distribution of industrial phospates by end use is detergent builders and cleaners, 44%; miscellaneous, 26%; food and beverage, 19%; metal treatment, 6%; and water treatment, 5% (Chemical Market Reporter, 1996e). Market conditions for sodium phosphates began to improve by yearend and were expected to continue to rebound in 1997 and 1998.

Demand for sodium silicates appeared strong in 1996 as producers ran at about 88% of capacity; however, some plants closed to consolidate and raise individual plant operating rates at other sites. About 1.15 million tons of sodium silicates were produced in 1996.

Sodium chromates, another important use for soda ash, remained flat during 1996 with little optimism for growth in the next few years. The industry has been adversely affected by legislation that restricted the quantity of chrome used in manufacturing industrial enamels, particularly medium chrome yellow that is used in traffic paints.

Soaps and Detergents.—Detergents are the third largest use of soda ash. Soda ash is used as a builder to emulsify oil stains, reduce the redeposition of dirt during washing and rinsing, provide alkalinity for cleaning, and soften laundry water. In addition, soda ash is a component of sodium tripolyphosphate, another major builder in detergent formulations, but soda ash consumption has been decreasing because phosphatic detergents may contribute to the environmental problem of eutrophication. Many regions of the nation have adopted phosphate detergent limitations or bans. These areas represent about 40% of the U.S. population. In response to the environmental issue, detergent manufacturers began reformulating detergents to make

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compact and superconcentrated products. These reformulations require sodium silicates and synthetic zeolites, which are made from soda ash. Liquid detergents, which do not contain any soda ash, compete with powdered detergents and command 40% of the household laundry detergent market, up from only 15% in 1978. With the October 1 price increase announcement by the soda ash producers, detergent formulators threatened to convert back to caustic soda because its price had been declining since the third quarter (European Chemical News, 1996a).

Stocks

Yearend stocks of dense soda ash in domestic plant silos, warehouses, terminals, and on teamtracks amounted to 271,000 tons. Producers indicate that a potential supply problem could exist when inventories fall below 180,000 tons. Most consumers of soda ash do not have storage facilities to accommodate large quantities of soda ash and must rely on suppliers to provide the material on a timely basis.

Prices

About 38% of U.S. soda ash production is exported with the remainder for domestic consumption. In the domestic market, the large volume buyers of soda ash are primarily the major glass container manufacturers, whose purchases are seasonal (more beverage containers made in second and third quarters for summertime beverage consumption). Soda ash sales to the flat glass sector are usually dependent on the state of the economy because the largest use of flat glass is in automobile manufacture and residential housing and commercial building construction. These two major industrial sectors are especially sensitive to changing economic conditions. If construction starts and automobile sales are up, soda ash sales will proportionally follow.

The average annual value for bulk, dense natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA, was $91.05 per ton ($82.60 per short ton), which was an 11% increase over that of 1995. The value is not a "price;" it is the value of the combined revenue of California and Wyoming bulk dense soda ash sold on an f.o.b. plant basis at list, spot, or discount prices, on long-term contracts, and for export, divided by the quantity of soda ash sold. The list prices quoted in trade journals or by producers differ from the annual average values reported to and by the USGS. This value may or may not correspond to the posted list prices. The list price for Wyoming bulk, dense soda ash was raised effective July 1, 1995, or as contracts permit, to $105 per short ton from $98 per short ton. The California price for the comparable product also increased by $7 per ton; from $123 per short ton to $130 per short ton. *(See table 4.)*

Effective October 1, 1996, Solvay Minerals increased its off-list price for soda ash by $5 per ton, not to exceed the list price of $105 per ton in bulk and $153 per ton in 100-pound bags. Although many of the other producers followed, the price increase attempt was not successful by yearend (Chemical Market Reporter, 1996f).

Foreign Trade

U.S. soda ash exports increased 8% in 1996 to 3.84 million tons, which set another record. U.S. exports to 50 countries, on a regional basis, were as follows: Asia, 46%; South America, 21%; North America, 16%; Europe, 6%; Africa and the Middle East, 4% each; Oceania, 2%; Central America, 1%; and the Caribbean, negligible. The average "free alongside ship" value was $132.29 per ton in 1996 compared with $124.65 per ton in 1995. The top 10 countries that represented 71% of total U.S. soda ash exports were, in decreasing order, Indonesia, Mexico, Japan, the Republic of Korea, Thailand, Canada, Venezuela, Brazil, Taiwan, and the South Africa. *(See tables 5 and 6.)*

On July 13, the European Commission, which is the administrative section of the European Union (EU), was requested by FMC Wyoming Corp., General Chemical Corp., North American Chemical Co., and OCI Chemical Corp., to conduct an interim review of the antidumping duties imposed on the industry earlier. The four U.S. soda ash companies cited that the enlargement of the EU with the addition of Austria, Finland, and Sweden alters the basis for antidumping allegations (Chemical and Engineering News, 1996). European producers challenged the request stating that the three new countries account for only 5% of EU soda ash consumption. Furthermore, Austria and Finland previously had voted in favor of the antidumping duties. The four U.S. companies presently are subject to antidumping duties ranging from 2.5% to 8.9% as well as an import duty of 7.3%. European soda ash producers proposed raising prices that caused an intensive lobbying effort on behalf of the U.S. soda ash producers by European glass producers. Despite that the price increases were the first in 3 years, the glass industry petitioned the Commission to eliminate the antidumping duties on U.S. soda ash imports citing the European soda ash producers have improved their market position and no longer need import protection (Chemical Market Reporter, 1996g). The Commisson continued its investigation through the end of 1996 and may release its decision in 1997.

Although the United States exported 222,000 tons of soda ash to Europe in 1996, the material was not subject to the antidumping duties because there is a provision in the legislation that permits soda ash to enter duty-free as long as that quantity is incorporated into products (such as glass) of total comparable contained weight that are exported by that country. Therefore, there is no effect on the European market and no injury to the European soda ash producers.

Despite a 30% import duty, ANSAC exported about 22,000 tons of soda ash in August to India that resulted in a protest by the Indian Monopolies and Restrictive Trade Practices Commission. The complaint was initiated by the Alkali Manufacturers Association of India, which represents all the domestic soda ash producers. The Commission determined that ANSAC violated the provisions of the country's restrictive trade practices laws and passed an order banning ANSAC, but not its individual members, from shipping to India (Industrial Minerals, 1996d). ANSAC also was involved in an antidumping suite by Brazil in September.

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World Review

The largest consumers of soda ash tend to be the developed nations; however, these countries also usually have lower growth rates compared with developing countries that have greater demands for consumer products. Although the production and consumption quantities vary among the countries, the end-use patterns are basically the same (e.g., glass, chemicals, and detergents are the major sectors). The United States is the largest soda ash-producing country in the world. *(See table 8.)*

Nine countries have the capacity to produce more than 1 million tons annually. They are, in descending order, the United States, China, Russia, India, Germany, France, Japan, Poland, and the United Kingdom. Bulgaria, Romania, and the Ukraine have production installations that had been rated at about 1 million tons; however, adverse economic conditions have caused these nations to produce below their design capacities. Most of these soda ash-producing countries have large populations that require consumer products made with soda ash. The lesser developed nations tend to have greater soda ash demand and higher rates of growth as soda ash-consuming industries are developed.

Solvay S.A. of Belgium announced plans to expand soda ash production capacity at its plant in Rosignano, Italy, which will be increased to 1 million tons per year by 1998. Solvay recently completed capacity expansion in Torrelavega, Spain from 900,000 tons to 950,000 tons and in Povoa, Portugal from 180,000 tons to 230,000 tons. These increases raise Solvay's total European capacity to 4.2 million tons (Press Release - Solvay S.A., 1996).

Australia.—On April 1, 1996, D. George Harris and Associates purchased Penrice Soda Products Pty. Ltd., of Osborne. The purchase includes the synthetic soda ash plant with an annual capacity of 385,000 tons of soda ash and 24,000 tons of sodium bicarbonate, the solar salt facility of Penrice Saltfields Products at Dry Creek, and the limestone quarry of Penrice Quarry Products in Angaston. Although terms of the agreement were not disclosed by either party, the Australian press estimated the transaction at $81.5 million. Penrice had sales of $80 million in 1995 (Industrial Minerals, 1996e).

Bulgaria.—In an effort to raise $1 billion from the sale of some of its chemical, refining, and industrial enterprises, the Bulgarian State-owned company, Sodi Devnya, offered a 60% share of its 1.2-million-to-per-year soda ash operation for sale. Among the interested parties were Solvay S.A., LG Chemicals, Brunner Mond & Co., D. George Harris and Associates, General Chemical Corp., Anglovaal Ltd., and several Nordic and East European firms (Industrial Minerals, 1996f). General Chemical offered $160 million, which was $40 million higher than the second highest bid (European Chemical News, 1996b). By yearend, General Chemical reversed its decision to acquire the soda ash plant that allowed Solvay to become the apparent winner; however, a final decision was expected by February 28, 1997 (Chemical Market Reporter, 1996h).

Botswana.—Severe rains damaged the walls of the evaporation ponds and diluted the brines at the soda ash facility at Sua Pan of Botswana Ash, the successor company of the refinanced Soda Ash Botswana. A two-month stockpile of soda ash was available to meet the temporary demand by its customers. Production was reduced to about one-half of what had been produced but still far below its production capacity. The majority of the output had been marketed in South Africa, which began importing soda ash from ANSAC in the United States (Industrial Minerals, 1996g).

France.—Rhône-Poulenc S.A. announced a divestiture program to raise $1 billion to $1.5 billion to reduce the company's debt through selling its chemical commodity businesses, which included soda ash. As a result, Rhône-Poulenc sold its Wyoming natural soda ash operation to OCI of the Republic of Korea and its 600,000-ton-per-year synthetic soda ash plant in Nancy, France, which was managed by a wholly owned subsidiary of Rhône-Poulenc Chimie, Novacarb, to the Harris Chemical Group, which owned a natural soda ash plant in California, and synthetic soda ash plants in Australia and Germany. Harris Chemical will market the materia,l while Novacarb will continue to operate the plant through 1998, when Harris will acquire the entire operation (Chemical Market Reporter, 1996i; European Chemical News, 1996c).

Japan.—Tosoh Corp. of Japan closed its 320,000-ton plant in Shinnanyo, Yamaguchi Prefecture, in September 1996 and imported soda ash from its U.S. joint-venture operation in Wyoming. Tosoh Wyoming Inc. owns 24% of the General Chemical Corp. facility. Tosoh has about 200,000 tons of the total Japanese soda ash market, which is about 1.3 million tons.

Poland.—As part of a plan to privatize its state-owned chemical operations, Poland sold a 75% share in Janikosoda S.A. and Soda Matwy S.A., the two synthetic soda ash plants with a combined annual capacity of 1 million tons, to Ciech, the Polish chemical trading company. Ciech agreed to purchase the facilities for $78 million and invest another $128.5 million over the next 10 years (Industrial Minerals, 1996h).

Saudi Arabia.—The Arabian Mining and Manufacturing Co. awarded a contract to Hitachi Zozen Corp. and Marubeni Corp., both of Japan, to construct a synthetic soda ash facility near Jubail. The plant will have an annual capacity of 264,000 tons of light and dense soda ash, 90% of which will be consumed locally with the remainder for export. The $176 million project is expected to be in operation by mid-1998. Akzo Nobel of the Netherlands will provide the technology. Total cost of the project was estimated at $267 million, of which $107 million will come from a loan from the Saudi Industrial Development Fund and the balance from commercial banks (European Chemical News, 1996d).

Turkey.—Discussions resumed between Rio Tinto Zinc (RTZ) and FMC Corp. with Etibank, the state mining agency regarding developing the trona deposit at Beypazari, near Ankara. Negotiations with various U.S. companies have occurred during the past 13 years but talks with these two companies were suspended when the present political coalition came into office in June 1996 when Etibank announced it would develop the deposit itself. The proposed project would cost

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develop the deposit itself. The proposed project would cost about $400 million for a 1 million-ton-per-year soda ash operation. (MEED, 1996).

Outlook

Exports will continue to be the driving force behind increasing U.S. soda ash production capacity, especially to countries that are joint-venture partners with U.S. companies. Some of these countries will continue to evaluate the economics of closing certain synthetic soda ash facilities and importing soda ash from their U.S. subsidiaries. Total U.S. exports are forecast to increase an additional 400,000 tons in 1997, especially to Asia and South America. Joint-venture partnerships with developing nations involving new technology will stimulate economies in those countries and increase soda ash sales. The automotive manufacturing industry in South America is expanding considerably. Chrysler, Peugeot, Renault, Mercedes-Benz, Honda, and Toyota announced they will construct new assembly plants while Ford, General Motors, and Volkswagon will expand existing facilities. This will require a lot of new flat glass for automotive windows for the estimated 2 million vehicles that are planned to be manufactured by the end of this century.

Owens-Corning Fiberglass Co., announced plans to form a partnership with China for fiberglass insulation manufacture. Asahi Glass Co. of Japan formed a joint venture to produce flat glass in Song Be, Vietnam. Asahi also invested between $56 million to $66 million to expand flat glass production at Teplice in the Czech Republic. Saint-Gobain is scheduled to bring on-stream in 1998 a float glass plant in Ravong, Thailand, with an annual capacity of 350,000 tons of glass. Other flat glass projects are scheduled for construction in Brazil, Germany, and Indonesia that will require soda ash, the majority of which should be supplied from the United States.

Domestic soda ash consumption should rise in 1997 as FMC increases its shipments of soda ash to DuPont's titanium dioxide plant in Tennessee. Reportedly, about 230,000 tons of soda ash will be required annually for this use. Domestic apparent consumption for 1997 is forecast at 6.5 million tons.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT SODA ASH STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Production 2/	9,380	8,960	9,320	10,100	10,200
Value 2/	$837,000	$734,000	$724,000	$829,000	$926,000
Value, average annual:					
Per short ton	$80.93	$74.34	$70.44	$74.50	$82.60
Per metric ton	$89.21	$81.95	$77.65	$82.12	$91.05
Production, Wyoming trona	14,900	14,500	14,600	16,500	16,300
Exports	2,960	2,800	3,230	3,570	3,840
Value	$434,000	$376,000	$406,000	$445,000	$508,000
Imports for consumption	72	89	79	83	107
Value	$12,800	$17,100	$12,100	$12,000	$14,700
Stocks, Dec. 31: Producers'	371	274	203	306	271
Consumption:					
Apparent	6,360	6,350	6,240	6,510	6,470
Reported	6,320	6,280	6,260	6,500	6,390
World: Production	30,700	29,500	29,300 r/	30,300 r/	30,400 e/

e/ Estimated. NA Not available.

1/ Data are rounded to three significant digits.

2/ Natural only, soda liquors and purge liquors converted to soda ash equivalent are as follows: 1992, 121,000 tons; 1993, 85,100 tons; 1994, 92,000 tons; 1995, 105,000 tons; and 1996 withheld to avoid disclosing company proprietary data.

TABLE 2
U.S. PRODUCERS OF SODA ASH IN 1996

(Million short tons, unless otherwise noted)

Company	Plant nameplate capacity	Plant location	Source of sodium carbonate
FMC Wyoming Corp. 1/	3.55	Green River, WY	Underground trona.
General Chemical (Soda Ash) Partners 2/	2.40	do.	Do.
North American Chemical Co. 3/	1.45	Trona, CA	Dry lake brine.
OCI Chemical Corp. 4/	2.30	Green River, WY	Underground trona.
Solvay Minerals Inc. 5/	2.30	do.	Do.
Tg Soda Ash Inc. 6/	1.30	Granger, WY	Do.
Total	13.30		
Total million metric tons	12.07		

1/ Formed joint venture (20%) in Feb. 1996 with Sumitomo Corp. and Nippon Sheet Glass Co., Ltd., both of Japan.

2/ A joint venture between General Chemical Corp. (51%), Australian Consolidated Industries International (ACI-25%), and TOSOH Wyoming Inc. of Japan (24%), which purchased part of ACI's share in June 1992.

3/ Oriental Chemical Industries of Korea as a partner had 27% equity share, but was reduced to about 7% in 1993.

4/ Rhone-Poulenc of France sold its 51% share to Oriental Chemical Industries (OCI) of Korea on Feb. 29, 1996; Union Pacific Resources Co. owns 49%.

5/ Solvay Soda Ash Joint Venture is owned by Solvay S.A. of Belgium (80%) and Asahi Glass Co. of Japan (20%), which became a partner in Feb. 1990. Capacity increase of 272,000 tons (300,000 short tons) installed Dec. 1995.

6/ Owned by Texasgulf Inc., subsidiary of Societe Nationale Elf Aquitaine of France (100%).

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TABLE 3
REPORTED CONSUMPTION OF SODA ASH IN THE UNITED STATES, BY END USE, BY QUARTERS 1/

(Metric tons)

SIC Code	End use	1995 total	1996 First quarter	1996 Second quarter	1996 Third quarter	1996 Fourth quarter	1996 Total
32	Glass:						
3221	Container	1,690,000	372,000	409,000	392,000	379,000	1,550,000
3211	Flat	979,000	218,000	252,000	261,000	275,000	1,010,000
3296	Fiber	214,000	59,500	58,600	58,600	59,700	236,000
3229	Other	248,000	66,100	60,700	60,100	60,300	247,000
	Total	3,130,000	716,000	780,000	771,000	773,000	3,040,000
281	Chemicals	1,650,000	385,000	411,000	444,000	446,000	1,690,000
284	Soaps and detergents	783,000	204,000	190,000	201,000	191,000	785,000
26	Pulp and paper	186,000	49,900	50,000	42,800	40,400	183,000
2899	Water treatment 2/	108,000	19,000	21,700	24,100	21,700	86,500
	Fluegas desulfurization	130,000	36,100	35,100	44,000	36,700	152,000
	Distributors	323,000	77,600	79,900	76,500	80,200	314,000
	Other	185,000	35,700	37,100	35,100	37,300	145,000
	Imports 3/	82,700	25,000	25,700	27,400	28,800	107,000
	Total domestic consumption	6,500,000	1,520,000	1,600,000	1,640,000	1,630,000	6,390,000
	Exports 4/	3,600,000	903,000	987,000	1,040,000	1,000,000	3,930,000
	Canada	180,000	52,500	50,500	57,700	65,500	226,000
	Total industry sales 5/	10,100,000	2,430,000	2,590,000	2,680,000	2,630,000	10,300,000
	Total sales from plants	9,760,000	2,320,000	2,620,000	2,610,000	2,590,000	10,100,000
	Total production	10,100,000	2,370,000	2,620,000	2,550,000	2,630,000	10,200,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes soda ash equivalent from soda liquors and purge liquors sold to powerplant for water treatment. Sales of mine water are excluded.

3/ Data are from the Bureau of the Census and may vary from the quantity reported by the producer/importer. Actual imports are proprietary data but have been distributed into appropriate end-use categories and included in "Total Domestic Consumption."

4/ As reported by producers. Includes Canada. Data may not necessarily agree with that reported by the Bureau of the Census for the same periods.

5/ Represents soda ash from domestic origin (production and inventory changes) and imports and for exports. Includes soda ash sold by coproducers and distributed by purchasers into appropriate end-use categories.

TABLE 4
SODA ASH YEAREND PRICES

		1995	1996
Sodium carbonate (soda ash):			
Dense, 58%, Na2O 100-pounds, paper bags, carlot, works, f.o.b.	per short ton	$153.00	$153.00
Bulk, carlot, same basis tons	do.	105	105
Light 58%, 100-pounds, paper bags, carlot same basis	do.	158	158
Bulk, carlot, same basis tons	do.	110	110

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V.249, No. 1, Jan. 1, 1996, p. 32, and V. 251, No. 1, Jan. 6, 1997. p. 28.

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TABLE 5
REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS, IN 1996 1/

(Metric tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percent of total
Atlantic:											
Baltimore, MD	--	--	--	--	315	--	--	--	--	315	--
Charleston, SC	--	--	--	--	383	--	--	--	--	383	--
Miami, FL	--	--	36	39	--	--	--	--	--	75	--
New York, NY	--	--	--	--	1,730	--	16	2,090	--	3,840	--
Philadelphia, PA	--	--	34	--	--	--	--	--	--	34	--
Savannah, GA	--	7	--	--	--	--	--	--	--	7	--
Wilmington, NC	--	--	--	--	778	--	--	--	--	778	--
Gulf:											
Houston-Galveston, TX	--	21	1,890	2,930	7	--	--	500	--	5,350	--
New Orleans, LA	5	--	--	--	--	--	--	--	--	5	--
Port Arthur, TX	--	--	229,000	12,000	12,300	22,600	32,000	--	--	308,000	8
Pacific:											
Columbia-Snake River	--	20,900	346,000	--	164,000	137,000	74,600	1,530,000	74,400	2,340,000	61
Los Angeles, CA	--	--	--	--	--	--	--	326	319	645	--
San Diego, CA	13,100	4,920	211,000	--	42,500	6,760	62,000	242,000	--	583,000	15
San Francisco, CA	--	--	--	--	68	--	--	40	242	350	--
Seattle, WA	10,000	--	--	--	--	--	--	608	--	10,700	--
North Central:											
Detroit, MI	137,000	--	--	--	167	--	--	--	--	137,000	4
Duluth, MN	51	--	--	--	--	--	--	--	--	51	--
Great Falls, MT	16,500	--	--	--	--	--	--	--	--	16,500	--
Pembina, ND	10,000	--	--	--	--	--	--	--	--	10,000	--
Northeast:											
Buffalo, NY	41,900	--	--	--	--	--	--	--	--	41,900	1
Ogdensburg, NY	1,310	--	--	--	124	--	--	--	--	1,440	--
St. Albans, VT	1,220	--	--	--	--	--	--	--	--	1,220	--
Southwest:											
Laredo, TX	354,000	--	--	--	--	--	--	--	--	354,000	9
Nogales, AZ	89	--	--	--	--	--	--	--	--	89	--
Unknown:	17,900	--	--	--	--	--	--	--	--	17,900	--
Total	603,000	25,800	788,000	15,000	222,000	166,000	169,000	1,770,000	74,900	3,840,000	100
Percent of total	16	1	21	--	6	4	4	46	2	100	--

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census as adjusted by the U. S. Geological Survey using trade data and information from the Journal of Commerce.

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TABLE 6
U.S. EXPORTS OF SODA ASH, BY COUNTRY 1/

(Thousand metric tons)

Country	1995 Quantity	1995 Value (thousands)	1996 Quantity	1996 Value (thousands)	Country	1995 Quantity	1995 Value (thousands)	1996 Quantity	1996 Value (thousands)
Argentina	121	$15,400	92	$13,000	Japan	339	$41,800	327	$43,200
Australia	31	3,570	56	6,610	Korea, Republic of	277	39,300	311	45,900
Belgium	23	3,910	72	10,200	Malaysia	78	11,200	76	11,500
Belize	6	1,010	--	--	Mexico	397	35,900	367	39,600
Bolivia	4	726	6	1,050	New Zealand	20	2,270	19	2,210
Brazil	233	31,400	209	27,300	Nigeria	--	--	5	500
Canada	187	15,700	236	21,800	Panama	4	575	4	580
Chile	78	10,500	123	17,000	Peru	19	3,010	24	3,920
China	50	6,260	45	6,210	Philippines	103	13,200	94	13,200
Colombia	86	12,300	98	14,200	Poland	--	--	15	1,430
Costa Rica	16	2,330	4	617	Saudi Arabia	65	5,820	134	14,000
Croatia	27	3,650	34	3,310	Singapore	26	3,450	17	2,340
Dominican Republic	3	515	4	710	South Africa	112	13,900	164	22,200
Ecuador	11	1,370	6	816	Spain	97	9,350	78	8,050
El Salvador	4	715	3	438	Taiwan	198	26,600	182	26,200
France	5	702	--	--	Thailand	263	36,000	285	41,300
Germany	(2/)	(2/)	1	104	Trinidad and Tobago	35	1,970	7	1,510
Guatemala	18	3,020	15	2,320	Turkey	--	--	19	1,970
India	--	--	23	2,060	United Arab Emirates	16	1,580	10	1,020
Indonesia	343	46,600	414	59,700	Uruguay	5	641	2	344
Iran	25	2,230	--	--	Venezuela	210	32,200	227	36,000
Ireland	(2/)	(2/)	2	220	Other 3/	1	174	1	187
Israel	33	4,080	23	2,790	Total	3,570	445,000	3,840	508,000
Jamaica	2	682	4	693					

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit, included with "Other."

3/ Includes The Bahamas (1995), Bahrain (1995), Barbados (1995), Finland (1995), Ghana (1996), Honduras (1996), Hong Kong, Federated States of Micronesia '(1995), the Netherlands, Russia, Sweden (1996), the United Kingdom, and Uzbekistan (1996).

Source: Bureau of the Census, as adjusted by the U. S. Geological Survey, using Journal of Commerce trade data and information.

TABLE 7
U. S. PRODUCTION OF SODIUM COMPOUNDS, BY MONTH 1/

(Metric tons)

	1995 Soda ash	1995 Caustic soda 2/	1995 Wyoming trona	1996 Soda ash	1996 Caustic soda 2/	1996 Wyoming trona
January	840,000	15,900	1,460,000	762,000	14,000	1,480,000
February	698,000	11,400	1,220,000	814,000	17,000	1,360,000
March	867,000	15,600	1,490,000	789,000	18,900	1,360,000
April	837,000	18,200	1,360,000	855,000	16,900	1,320,000
May	843,000	16,600	1,380,000	876,000	17,600	1,370,000
June	816,000	10,100	1,350,000	885,000	20,400	1,250,000
July	860,000	13,500	1,440,000	850,000	20,000	1,430,000
August	840,000	20,300	1,380,000	847,000	17,600	1,320,000
September	845,000	18,500	1,430,000	857,000	22,000	1,350,000
October	870,000	17,000	1,390,000	909,000	20,400	1,460,000
November	876,000	12,800	1,270,000	859,000	18,900	1,270,000
December	907,000	14,500	1,320,000	866,000	18,500	1,330,000
Total	10,100,000	184,000	16,500,000	10,200,000	222,000	16,300,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ As soda ash equivalent.

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TABLE 8
SODA ASH: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country	1992	1993	1994	1995	1996 e/
Albania e/	(3/)	--	--	--	--
Australia e/	300	300	300	300	300
Austria e/	150	150	150	200	200
Belgium e/ 4/	375	300	-- r/	-- r/	--
Bosnia and Herzegovina e/	25	20	15	15	15
Botswana	124	126	174	202	100
Brazil e/	200	200	200	200	200
Bulgaria	517	259	300 e/	300 e/	300
Canada e/	305	305	300	300	300
China e/	4,500	5,270	5,680	5,820	6,390
Colombia e/ 5/	121	121	-- r/	-- r/	--
Czechoslovakia 6/	100 e/	XX	XX	XX	XX
Egypt e/	51	51	51	51	51
France	1,100	1,222	1,123 r/	1,120 r/	1,100
Germany	1,639 r/	1,586 r/	1,380	1,400 e/	1,400
India e/	1,500	1,500	1,500	1,500	1,500
Italy e/	600	500	500	500	500
Japan	1,057	1,056	1,050	1,049 r/	1,050
Kenya 7/	186	145	226 r/	218 r/	220
Korea, Republic of e/	300	310	310	310	320
Mexico e/ 8/	440	440	290 r/	290 r/	290
Netherlands e/	400	400	400	400	400
Pakistan	146 e/	186	185 r/	180 e/	185
Poland	929	815	997	1,019 r/	1,000
Portugal e/	150	150	150	150	150
Romania	452	371	449 r/	350 e/	350
Russia	2,679 r/	1,992 r/	1,585 r/	1,823 r/	1,460
Spain e/	500	500	500	500	500
Taiwan	91 r/	89 r/	128 r/	128 r/	128
Turkey e/	385	385	385	385	390
Ukraine e/	1,000	800	660	475	425
United Kingdom e/	1,000	1,000	1,000	1,000	1,000
United States 7/	9,380	8,960	9,320	10,100	10,200 9/
Total	30,700	29,500	29,300 r/	30,300 r/	30,400

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through Apr. 21, 1997. Synthetic unless otherwise specified.

3/ Less than 1/2 unit. Plant at Vlora reportedly closed in 1993.

4/ Plant at Couillet closed by yearend 1993.

5/ Plant closed in 1993.

6/ Dissolved on Dec. 31, 1992.

7/ Natural only.

8/ Includes natural and synthetic. Estimated production of natural soda ash, in metric tons, was as follows: 1992--160,000 and 1993--160,000. Natural soda ash operation closed in Aug. 1993.

9/ Reported figure.

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SODIUM SULFATE

By Dennis S. Kostick

Sodium sulfate, also known as disodium sulfate (Na_2SO_4), is an inorganic chemical that has several important industrial uses. It is produced from naturally occurring sodium sulfate-bearing brines or crystalline evaporite deposits, and as a byproduct of a varity of chemical manufacturing processes, such as ascorbic acid, battery acid recycling, boric acid, cellulose, chromium chemicals, lithium carbonate, rayon, resorcinol, and silica pigments. The byproduct sodium sulfate is considered a waste product but has marketability; both types of sodium sulfate, however, have several important and useful applications in various consumer products.

Production

Domestic production and inventory data for natural sodium sulfate are developed by the U.S. Geological Survey (USGS) from monthly and annual surveys of U.S. operations. Of the two natural sodium sulfate operations to which a survey request was sent, both responded, representing 100% of the natural sodium sulfate data used in this report.

Synthetic sodium sulfate data were collected by the U.S. Department of Commerce, Bureau of the Census, from quarterly and annual surveys (aggregate data published in Current Industrial Reports, Inorganic Chemicals, MQ28A and MA28A) of companies engaged in recovering and selling byproduct sodium sulfate. Any revised Bureau of the Census data have been included using the most recent statistics. These data are aggregated with USGS natural sodium sulfate data and included in several tables.

Two companies produced natural sodium sulfate from a total of two plants in California and Texas. The domestic natural sodium sulfate industry supplied 56% of the total output of U.S. sodium sulfate. Because of the location of these plants, most natural sodium sulfate is marketed in the West and Southern Gulf areas. Based on final 1995 data from the Bureau of the Census, byproduct material was supplied by 14 establishments located primarily in the Midwest and Mid-Atlantic regions. The number of plants, by process, was natural, two; viscose rayon, three; sodium dichromate, one; and phenol, boric acid, formic acid, and other, eight. Total rated production capacity in 1996 was 762,000 tons, and the industry operated at 72% of this capacity.

Domestic natural sodium sulfate production decreased about 6% in 1996. Final 1996 statistics on synthetic sodium sulfate are unavailable because these data are usually subject to major revisions in updated reports issued by the Bureau of the Census. However, based on preliminary Bureau of the Census data for total sodium sulfate, 551,000 tons were produced in 1996, of which 327,000 tons were from natural sources and 245,000 tons were from byproduct sources. The quantity of byproduct material reported by the Bureau of the Census was less than expected, based on the strength of certain domestic and export sales and the opinions of industry analysts. Ending inventories of natural sodium sulfate were 19,000 tons.

Although GNB Technologies of Columbus, GA, came on-stream in 1995 with a battery acid recycling plant that recovers byproduct sodium sulfate, the operation had some technical difficulties in achieving its annual capacity of 27,000 tons (30,000 short tons). East Penn Manufacturing in Lyons Station, PA commissioned its new battery recycling facility in 1996. Its planned annual capacity was 4,000 tons of byproduct sodium sulfate (Chemical Marketing Reporter, 1996a). Occidental Chemical Corp.'s sodium dichromate plant in Castle Hayne, NC, contracted with Wheelabrator Water Technologies to develop technology in refining the chrome cake to detergent-grade sodium sulfate. Completion of the project was scheduled for mid-1997 (Chemical Marketing Reporter, 1996a).

Schuylkill Metals Corp., a battery recycling company that was scheduled to begin recovery of sodium sulfate in early 1997, retained Prior Chemical Corp. as its exclusive sales agent for its anhydrous sodium sulfate business at its Baton Rouge, LA facility (North American News, 1996).

DLD Resources acquired the hydrochloric acid facility at Hobbs, NM that was owned by Climax Chemical Co. Because of the growing demand for sodium sulfate, the plant was to be restarted to recover sodium sulfate that would be marketed to the regional oil well drilling industry. When in full operation in 1997, the plant is scheduled to have an annual capacity of 35,000 to 40,000 tons of byproduct sodium sulfate (Chemical Marketing Reporter, 1996b). Hellier & Moyle Resources, Inc., was formed to market the sodium sulfate from DLD (Chemical Marketing Reporter, 1996c).

Consumption

The estimated distribution of sodium sulfate by end use was soap and detergents, 42%; textiles, 15%; pulp and paper, 12%; glass 11%; and other, 20%. Miscellaneous uses included sodium sulfate for carpet fresheners and starch manufacture. Based on preliminary byproduct sodium sulfate production data, apparent consumption decreased 25% to 552,000 tons. However, industry analysts indicate that this amount was less than expected based on strong export and domestic sales.

The U.S. sodium sulfate industry continued to benefit from the strong demand for detergents and general supply shortages of sodium. The demand for less expensive consumer products

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led detergent manufacturers to reformulate powdered home laundry products using more sodium sulfate as filler. The Mexican natural sodium sulfate producer, Quimica del Rey, continued to divert a majority of its supply normally dedicated for export to furnish the Mexican demand requirements. This allowed U.S. producers and others to fill the void in various world markets. Production of byproduct sodium sulfate in Japan also declined because of the downturn in Japanese rayon market.

An estimated 44% of the total sodium sulfate consumed in the United States is for use as a filler in powdered laundry detergents. Many areas in the country have adopted phosphate bans or limitations because it is believed that phosphatic detergents contribute to the environmental problems of eutrophication. The affected areas represent about 33% of the U.S. population. In response to this environmental issue, detergent manufacturers have reformulated many of their detergents by switching from sodium tripolyphosphate (STPP) to tetrasodium pyrophosphate, which has the same building power as STPP but requires less to be used, thereby reducing the amount of phosphate released into the environment. These reformulations used more sodium sulfate as filler, which was beneficial to the sodium sulfate industry.

Some domestic detergent manufacturers began adding additional quantities of sodium sulfate to powdered laundry products, reportedly to substitute for higher priced zeolites and surfactants.

The use of sodium sulfate in textiles apparently is increasing, according to industry sources. Salt traditionally has been used in the dyeing process to separate organic contaminants, promote "salting out" of dyestuff precipitates, and blending with dyes to standardize concentrated dyes. The equipment used in this process used stainless steel, which was susceptible to corrosion because of the salt. The textile industry began substituting sodium sulfate for the salt, which is not corrosive to the manufacturing equipment.

Stocks

Yearend 1996 inventories of natural sodium sulfate stored by the two producers were 19,000 tons, which was a 19% increase compared with 1995. The material stockpiled was anhydrous sodium sulfate. Synthetic sodium sulfate was marketed mainly through major chemical distributors, which have separate storage facilities from the producers.

Prices

Producers of natural sodium sulfate tend to market and sell most of their own product, but most synthetic producers use major chemical distributors or chemical supply companies as sales agents. The principal product made and sold by the synthetic sodium sulfate producer is the primary economic factor. Because sodium sulfate is considered a waste product, it will be sold at a price that ensures prompt sales. This practice tends to set the rates at which the natural product can be sold.

The list prices quoted in trade journals or by producers of all grades of sodium sulfate differ from the annual average values reported by the USGS. The value represents the combined amount of total revenue of domestic natural sodium sulfate sold at list prices, spot prices, long-term contracts, discounts, and export divided by the aggregated quantity of sodium sulfate sold. The published value does not necessarily correspond to the posted list price.

The average value increased from $84.55 per metric ton ($76.70 per short ton) in 1995 to $88.90 per metric ton ($80.64 per short ton) in 1996 for bulk sodium sulfate, f.o.b. mine or plant. Price increase announcements were made in late 1996 by Saskatchewan Minerals and Millar Western Industries, both of Canada, that raised the off-list price by $10 per ton. U.S. natural producers Elf Atochem North America Inc. and North American Chemical Co. followed the price initiative also by $10 per ton (Chemical Market Reporter, 1996d).

Foreign Trade

Sodium sulfate exports amounted to 86,000 tons, according to Bureau of the Census data. Of the 86,000 tons, crude sodium sulfate exports of 76,000 tons was exported to 14 nations. Canada received the largest share; about 34% of the total, followed by Colombia, 31%, and Brazil, 20%. Anhydrous sodium sulfate exports to 16 countries were nearly 10,000 tons. New Zealand imported the most; nearly 55% of the total.

Imports of sodium sulfate were 90,000 tons, or 37% less than the 143,000 tons imported in 1995. More than 29,000 tons of anhydrous sodium sulfate were imported in 1996, primarily from Canada and Mexico. Shipments from Canada represented nearly 97% of total imports of anhydrous sodium sulfate. Belgium, Germany, India, and Japan shipped the remainder. Imports of crude sodium sulfate were almost exclusively from Canada. The total value of all sodium sulfate imports was $96.76 per ton.

World Review

Approximately 67% of the world sodium sulfate production in 1996 was from natural sources; the balance was represented by synthetic sodium sulfate recovered from various chemical and manufacturing processes. Although the USGS collects or estimates data from 31 sodium sulfate-producing countries, other countries are known or assumed to have produced synthetic sodium sulfate, but production statistics are not reported, and available information is inadequate to make reliable estimates of output.

Although the United States is one of the largest producers in the world of natural and synthetic sodium sulfate, its share has decreased from 23% of world production total in 1980 to 11% in 1996.

Spain.—The Spanish sodium sulfate producer, Crimidesa, began constructing a third sodium sulfate facility in Burgos that will have an annual capacity of 150,000 tons. Completion of the project was scheduled for late 1997. The new operation will raise the company's total capacity to more than 500,000 tons.

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Demand for sodium sulfate in Europe was a motivating factor for the justification of the new project (Industrial Minerals, 1996).

Outlook

Sodium sulfate consumption by the soap and detergent industry, which has been the largest consumer of sodium sulfate, will continue to remain strong because of the demand for powdered home laundry products. In areas with a depressed economy, powdered home laundry detergents are more in demand because they are less expensive than liquid concentrates or compact alternatives.

U.S. consumption, which had been declining for many years, appears to be growing because of supply and demand changes in North America and in other parts of the world where sodium sulfate trade was important. Domestic sodium sulfate production should remain adequate to meet consumption requirements.

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[1]Prior to January 1996, Published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT SODIUM SULFATE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Production, natural	337	327	298	327	306
Production, synthetic	216	210	293 r/	318 r/	246
Synthetic and natural:					
High purity	345	320	W	W	W
Low purity (99% or less)	207	217	W	W	W
Total 2/	552	537	591 r/	645 r/	551
Value 3/	$50,800	$41,100	$48,000 r/	$54,500 r/	$49,000
Per ton	$91.79	$76.53	$81.25	$84.55	$88.90
Exports	155	89	65	66	86
Value	$11,900	$8,540	$7,020	$7,250	$9,140
Imports for consumption	158	163	190	143 r/	90
Value	$13,400	$13,600	$15,700	$11,800	$8,660
Stocks, Dec. 31: Producers	47	42	34	16	19
Apparent consumption	544	616	724 r/	740 r/	552
World: Production	4,630 r/	4,690 r/	4,840 r/	4,870 r/	4,870 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes natural and synthetic. Total production data for synthetic sodium sulfate, obtained from the Bureau of the Census, were revised in third quarter 1996 MQ28A Inorganic Chemicals, Current Industrial Report.

3/ The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.

TABLE 2
U.S. PRODUCERS OF NATURAL AND SYNTHETIC SODIUM SULFATE IN 1996

Product and company	Plant nameplate capacity (thousand metric tons)	Plant location	Source
Sodium sulfate, natural:			
North American Chemical Co., Westend plant	204	Trona, CA	Dry lake brine.
Ozark-Mahoning Co.	141	Seagraves, TX	Do.
Total	345		
Sodium sulfate, synthetic:			
Courtaulds North American Inc.	45	La Moyne, AL	Rayon manufacture.
East Penn Manufacturing	4	Lyons Station, PA	Battery recycling.
Flour Corp., Doe Run Co.	14	Boss, MO	Do.
FMC Corp.	41	Bessemer City, NC	Lithium carbonate.
4M Paper Corp.	6	Ft. Madison, IA	Pulping process.
GMB Technologies	27	Columbus, GA	Battery recycling.
Hampshire Chemicals 1/	3	Deer Park, TX	Pulping process.
Do. 2/	8	Nashua, NH	Chelating agents.
Indspec Chemical Corp.	35	Petrolia, PA	Resorcinol manufacture.
J. M. Huber	33	Etowah, TN	Silica pigment.
Do.	18	Havre de Grace, MD	Do.
Lenzing A.G.	41	Lowland, TN	Rayon manufacture.
Occidental Chemical Corp.	109	Castle Hayne, NC	Sodium dichromate manufacture.
Roche Vitamins & Chemicals 3/	24	Belvidere, NJ	Ascorbic acid.
Teepak, Inc.	9	Danville, IL	Cellulose manufacture.
Total	417		
Grand total	762		

1/ Formerly Pineville Kraft.

2/ Formerly W.R. Grace & Co.

3/ Formerly Hoffman-La Roche, Inc.

TABLE 3
SODIUM SULFATE YEAREND PRICES

		1995	1996
Sodium sulfate (100% Na2SO4):			
East, bulk, carlot, works, freight equalized	per ton	$113.00-$114.00	$113.00-$114.00
Gulf, bulk, carlot, same basis	do.	110.00	110.00
West, bulk, carlot, same basis	do.	127.00	127.00
Salt cake (100% Na2SO4):			
East, bulk, f.o.b. works	do.	82.00	82.00

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 249, no. 1, Jan. 1, 1996, p. 32, and v. 251, no. 1, Jan. 6, 1997, p. 28.

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TABLE 4
U.S. EXPORTS OF SODIUM SULFATE, BY COUNTRY 1/

Country	Disodium sulfate, salt cake		Disodium sulfate, other		Total	
	Quantity (metric tons)	Value 2/	Quantity (metric tons)	Value 2/	Quantity (metric tons)	Value 2/
1995:						
Argentina	--	--	14	$205,000	14	$205,000
Australia	56	$5,730	58	511,000	114	517,000
Brazil	19,500	1,490,000	14	24,200	19,500	1,510,000
Canada	17,100	1,470,000	--	--	17,100	1,470,000
China	--	--	32	39,300	32	39,300
Colombia	11,600	690,000	--	--	11,600	690,000
Denmark	--	--	(3/)	3,180	(3/)	3,180
Germany	179	19,600	--	--	179	19,600
Ghana	--	--	(3/)	2,640	(3/)	2,640
Guatemala	4,960	521,000	--	--	4,960	521,000
Jamaica	168	20,300	--	--	168	20,300
Japan	184	19,000	--	--	184	19,000
Korea, Republic of	--	--	70	24,200	70	24,200
Mexico	439	51,200	4,700	1,080,000	5,130	1,140,000
New Zealand	2,000	177,000	2,020	476,000	4,020	653,000
Philippines	305	43,900	--	--	305	43,900
Taiwan	11	3,540	--	--	11	3,540
United Kingdom	--	--	2	15,600	2	15,600
Venezuela	3,060	353,000	(3/)	3,840	3,060	357,000
Total	59,500	4,860,000	6,910	2,390,000	66,400	7,250,000
1996:						
Argentina	--	--	2,300	800,000	2,300	800,000
Australia	--	--	34	508,000	34	508,000
Belgium	28	4,130	--	--	28	4,130
Brazil	15,100	1,400,000	65	663,000	15,200	2,070,000
Canada	26,100	2,120,000	--	--	26,100	2,120,000
China	16	3,500	15	19,800	31	23,300
Colombia	23,800	1,170,000	5	4,680	23,800	1,180,000
Costa Rica	60	14,400	--	--	60	14,400
Dominican Republic	--	--	19	6,300	19	6,300
Guatemala	8,530	1,050,000	--	--	8,530	1,050,000
Haiti	--	--	9	18,900	9	18,900
Israel	--	--	5	7,500	5	7,500
Italy	55	8,240	--	--	55	8,240
Jamaica	80	12,800	--	--	80	12,800
Malaysia	--	--	1	3,360	1	3,360
Mexico	1,870	280,000	778	282,000	2,640	563,000
Netherlands	56	8,290	--	--	56	8,290
New Zealand	--	--	5,370	508,000	5,370	508,000
Panama	--	--	3	4,840	3	4,840
Peru	--	--	1,190	173,000	1,190	173,000
Philippines	142	34,000	--	--	142	34,000
Saudi Arabia	--	--	3	2,520	3	2,520
Spain	--	--	5	12,600	5	12,600
St. Kitts and Nevis	22	2,880	--	--	22	2,880
Thailand	--	--	1	7,590	1	7,590
Venezuela	19	2,760	--	--	19	2,760
Total	75,900	6,120,000	9,810	3,020,000	85,700	9,140,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ F.a.s. value at U.S. ports.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 5
U.S. IMPORTS OF SODIUM SULFATE, BY COUNTRY 1/

Country	Disodium sulfate, salt cake 2/ 3/		Disodium sulfate, other		Total	
	Quantity (metric tons)	Value 4/	Quantity (metric tons)	Value 4/	Quantity (metric tons)	Value 4/
1995:						
Belgium	--	--	1	$1,360	1	$1,360
Canada	69,800	$6,580,000	71,700	4,960,000	141,000	11,500,000
Germany	--	--	37	33,000	37	33,000
India	--	--	58	70,200	58	70,200
Japan	130	16,800	20	24,900	150	41,700
Mexico	--	--	822	153,000	822	153,000
Total	69,900	6,600,000	72,600	5,240,000	143,000	11,800,000
1996:						
Belgium	--	--	300	84,000	300	84,000
Canada	60,000	5,670,000	28,400	2,470,000	88,500	8,150,000
Germany	1	1,480	56	25,200	57	26,600
India	--	--	229	254,000	229	254,000
Japan	--	--	7	8,000	7	8,000
Mexico	--	--	414	140,000	414	140,000
United Kingdom	32	3,150	--	--	32	3,150
Total	60,100	5,680,000	29,400	2,980,000	89,500	8,660,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Salt cake is HTS No. 2833.11.1000.
3/ Includes Glauber's salt, HTS No. 2833.11.5050.
4/ C.i.f. value at U.S. ports.

Source: Bureau of the Census.

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TABLE 6
SODIUM SULFATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Natural:					
Argentina (mirabilite)	24,796	6,554	7,978 r/	10,604 r/	10,000
Canada 4/	282,000	320,000	317,000	311,000 r/	315,000
Chile e/	13,200	13,200	13,200	13,200	13,000
China e/ 5/	550,000 r/	600,000 r/	600,000 r/	650,000 r/	650,000
Egypt e/	41,000	25,600 6/	25,000	25,000	25,000
Iran	237,459	280,000	280,000 e/	280,000 e/	280,000
Mexico 7/ (bloedite)	534,445	500,000 e/	527,228 r/	500,000 r/ e/	525,000
Netherlands e/	22,000	20,000	20,000	20,000	20,000
South Africa	37,169	36,380	44,544	43,971	41,800
Spain e/ 8/	675,000	650,000	600,000	600,000	650,000
Turkey (concentrates)	75,058	170,680 r/	307,049 r/	300,000 r/ e/	300,000
Turkmenistan e/	100,000	100,000 r/	100,000 r/	100,000 r/	100,000
United States	337,000	327,000	298,000	327,000	306,000 6/
Total	2,930,000 r/	3,050,000 r/	3,140,000 r/	3,180,000 r/	3,240,000
Synthetic: e/					
Austria	120,000	120,000	120,000	100,000	100,000
Belgium	250,000	250,000	250,000	250,000	250,000
Bosnia and Herzegovina	5,000	1,000	500	500	500
Brazil	9,000	9,000	9,000	9,000	9,000
Chile 9/	46,407 6/	46,000	46,400	47,000	46,000
Finland	30,000	30,000	30,000	30,000	30,000
France	77,000 6/	62,000	65,000	70,000	70,000
Germany	113,660 6/	106,789 6/	113,000 6/	110,000	120,000
Greece	6,000	6,000	6,000	6,000	6,000
Hungary	6,000	6,000	6,000	6,000	6,000
Italy	125,000	125,000	125,000	125,000	125,000
Japan	242,771 6/	229,346 6/	200,111 r/ 6/	206,893 r/ 6/	210,000
Macedonia	3,000	1,000	1,000	1,000	1,000
Netherlands	15,000	15,000	15,000	15,000	15,000
Pakistan	1,000	1,000	1,000	1,000	1,000
Portugal	50,000	50,000	50,000	50,000	50,000
Serbia and Montenegro	10,948 6/	3,668 6/	3,500	3,500	3,000
Spain	150,000	150,000	150,000	150,000	150,000
Sweden	100,000	100,000	100,000	100,000	100,000
Turkey	30,000	30,000	30,000	30,000	30,000
United Kingdom	90,000	90,000	90,000	60,000	70,000
United States 10/	216,000 6/	210,000 6/	293,000 r/ 6/	318,000 r/ 6/	246,000 6/
Total	1,700,000	1,640,000	1,700,000 r/	1,690,000 r/	1,640,000
Grand total	4,630,000 r/	4,690,000 r/	4,840,000 r/	4,870,000 r/	4,870,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 20, 1997.

3/ In addition to the countries listed, Norway, Poland, Romania, and Switzerland are believed to have produced synthetic sodium sulfate, and other unlisted countries may also have produced this commodity, but production figures are not reported; general information is inadequate for the formulation of reliable estimates of output levels.

4/ Excludes byproduct production from chemical plants.

5/ Both natural and synthetic.

6/ Reported figure.

7/ Series reflects output reported by Industries Penoles and an additional 22,000 tons estimated production by Sulfato de Viesca.

8/ N_2SO_4 content of glauberite and thenardite.

9/ Byproduct of nitrate industry.

10/ Derived approximate figures; data presented are the difference between reported sodium sulfate production (natural and synthetic not differentiated) and reported natural sodium sulfate sold by producers (reported under "Natural" in this table).

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CRUSHED STONE

By Valentin V. Tepordei

Crushed stone is one of the most accessible natural resources and a major basic raw material used by construction, agriculture, and other industries utilizing complex chemical and metallurgical processes. Despite the relative low value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well-being of the Nation.

A total of 1.33 billion metric tons of crushed stone was produced for consumption in the United States in 1996, a 5.3% increase compared with the total production of 1995. This tonnage represents the highest production level ever recorded in the United States, indicating a continued increase in the demand for construction aggregates. *(See table 1.)*

About three-quarters of the crushed stone production continued to be limestone and dolomite, followed, in order of volume, by granite, traprock, sandstone and quartzite, miscellaneous stone, marble, calcareous marl, slate, volcanic cinder and scoria, and shell. *(See table 2.)*

Foreign trade of crushed stone continued to remain relatively small. Exports decreased 45.9% to 3.3 million tons, and the value decreased only 8.4% to $36 million compared with that of 1995.

Imports of crushed stone, including calcium carbonate, increased 4.1% to 11.3 million tons, and the value decreased slightly to $91.8 million. Domestic apparent consumption of crushed stone, which is defined as production for consumption (sold or used) plus imports minus exports, was 1.34 billion tons. *(See tables 1, 22, and 23.)*

Legislation

The Department of Transportation and Related Agencies Appropriation Act of 1997 (Public Law 104-205) was signed by the President on October 1, 1996. The act appropriated a record $20.3 billion for highway funding, an increase of $313 million over that of fiscal year 1996. The act also appropriated $1.46 billion for the Airport Improvement Program, an increase of $10 million over that of fiscal year 1996.

Production

Domestic production data for crushed stone are derived by the U.S. Geological Survey (USGS) from voluntary surveys of U.S. producers.

Of the 4,070 crushed stone operations surveyed, 3,117 operations with 3,645 quarries owned by 1,493 companies were active. Of these, 2,461 operations with 2,686 quarries, representing 79% of the total number of operations and 73.7% of the total number of quarries, operated by 1,013 companies reported to the USGS. Their total production represented 86.3% of the total U.S. crushed stone output. Of the 2,461 reporting operations, 659 operations with 693 quarries owned by 191 companies did not report a breakdown by end use. Their production represented 27.8% of the U.S. total and is included in table 13 under "Unspecified, actual" uses. The nonrespondent's production was estimated using employment data and/or adjusted production reports from prior years. The estimated production from 656 nonresponding operations with 959 quarries owned by 480 companies represented 13.7% of the U.S. total and is included in table 13 under "Unspecified, estimated" uses.

A total of 817 quarries were either idle or presumed to have been idle in 1996 because no information was available to estimate their production. Since the 1995 survey, 190 operations were closed down. Most of the idle or closed operations were small, temporary quarries operated by State or local governments.

A total of 1.33 billion tons of crushed stone was produced for consumption in the United States in 1996, a 5.3% increase compared with the revised 1995 total. This tonnage represents the highest production level ever recorded in the United States. *(See table 1.)* Of this total, 955 million tons, or 71.8%, was limestone and dolomite, 202 million tons, or 15.2%, was granite, and 95 million tons, or 7.1%, was traprock. The remaining 78 million tons, or 5.9%, was shared, in descending order of quantity, by sandstone and quartzite, miscellaneous stone, marble, calcareous marl, slate, volcanic cinder and scoria, and shell. *(See table 2.)*

A comparison of the four geographic regions indicates that in 1996, the South continued to lead the Nation in the production of crushed stone with 620 million tons, or 46.4%, of the total, followed by the Midwest with 397 million tons, or 29.8%, and the Northeast with 181 million tons, or 13.6%. About 76% of the total U.S. crushed stone output was produced in two geographic regions, the South and the Midwest. *(See table 3.)*

Of the nine geographic divisions, the South Atlantic led the Nation in the production of crushed stone with 319 million tons, or 24%, of the U.S. total. It was followed by the East North Central division with 249 million tons, or 18.7%, and the East South Central with 155 million tons, or 11.7%.

A comparison of the production data by the nine geographic divisions for 1995 and 1996 indicates that the output of crushed stone increased in all regions. The largest increases were recorded in the Mountain, +10.6%; the East South Central, +8.1%; and the Middle Atlantic, +7.8%.

Crushed stone was produced in every State except Delaware

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and North Dakota. The 10 leading States in the production of crushed stone were, in order of volume, Pennsylvania, Texas, Florida, Missouri, Illinois, Ohio, Georgia, Virginia, Kentucky, and North Carolina. Their combined production represented 51.4% of the national total.

Crushed stone was produced by 1,493 companies at 3,117 operations with 3,645 quarries. Leading U.S. producers were, in order of volume, Vulcan Materials Co., Martin-Marietta Aggregates, Cornerstone Construction & Materials, Inc., CSR America Inc., and Redland Aggregates North America.

In March, Tarmac America, Inc., of Norfolk, VA, announced the completion of an exchange of assets between Tarmac PLC of Wolverhampton, United Kingdom, and George Wimpey PLC of London, United Kingdom, in which Tarmac traded its private sector housing division in the UK for Wimpey's minerals and construction businesses. As the result of this exchange, Tarmac America acquired three quarries in Pennsylvania and New Jersey, five quarries in Canada, and 10 aggregates depots in Pennsylvania, Maryland, New Jersey, and Delaware (Rock Products, 1996).

In May, Rogers Group, Inc., of Nashville, TN, acquired three quarries known as M&M Rock located around Conway, AR, from McConnell Materials of Conway, AR,. The acquisition also included two asphalt plants and a concrete plant (Aggregates Manager, 1996c).

In October, Rogers Group acquired the Tidwell Quarry located in Hot Springs County, AR, from Tidwell Construction Co., Inc., and renamed it Glen Rose Quarry (Aggregates Manager, 1996b).

In November, Redland Genstar, Inc., of Hunt Valley, MD, sold its Middletown, VA, limestone quarry to Chemstone Corp., of Strasburg, VA, a subsidiary of Global Stone, Inc., of Oakville, Ontario, Canada (Pit & Quarry, 1996).

In October Oldcastle Inc./Materials Group of Washington, DC, a subsidiary of CRH PLC of Dublin, Ireland, announced the acquisition of Tilcon Inc. of New Britain, CT, and its 60 operations located in Connecticut, Delaware, Maine, Massachussettes, New Hampshire, New Jersey, New York, Rhode Island, and Vermont (Aggregates Manager, 1996a).

In November, Vulcan Materials Co. of Birmingham, AL, reported the purchase of one quarry from Black Rock Quarries, Inc., of Black Rock, AR.

Limestone.—The 1996 output of crushed limestone, including some dolomite, increased by 6.9% to 869 million tons valued at $4.4 billion compared with the revised 1995 total. *(See table 2.)* In addition to the quarries reporting only limestone, 60 operations with 62 quarries reported producing limestone and dolomite without making a distinction between the two kinds of stone. Their combined production, of 25.6 million tons was included with the limestone. The limestone totals shown in this chapter, therefore, include an undetermined amount of dolomite in addition to the dolomite reported separately.

Limestone was produced by 879 companies at 1,854 operations with 1,998 quarries in 47 States. In addition, 43 companies with 60 operations and 62 quarries reported producing limestone and dolomite from the same quarries.

The leading producing States were, in order of tonnage, Texas, Florida, Missouri, Kentucky, and Illinois; these five States accounted for 38.3% of the total U.S. output. *(See table 8.)* The leading producers were, in order of volume, Vulcan Materials Co., Martin Marietta Aggregates, Cornerstone Construction & Materials, Inc., CSR America, Inc., and Rogers Group, Inc.

Dolomite.—Production of dolomite decreased by 1.0% to 86 million tons valued at $447 million compared with the revised 1995 total. *(See table 2.)* Crushed dolomite was reportedly produced by 96 companies at 165 operations with 175 quarries in 25 States. An additional undetermined amount of dolomite is included in the total crushed limestone.

The leading producing States were, in order of tonnage, Ohio, Pennsylvania, Illinois, Michigan and New York; these five States accounted for 59.5% of the total U.S. output. (*See table 8.*) The leading producers were Cornerstone Construction & Materials, Inc., S.E. Johnson Co./Stoneco, Inc., Oldcastle Inc., National Lime & Stone Co., and ASARCO Incorporated/American Limestone Co.

Marble.—Production of crushed marble increased by 2.2% to 6.1 million tons valued at $42.6 million compared with 1995. *(See table 2.)* Crushed marble was produced by 14 companies with 24 operations and 49 quarries in 11 States. *(See table 9.)* The leading producers of crushed marble were, in order of tonnage, Florida Rock Industries, Inc., Georgia Marble Co., and CAMAS America, Inc.

Calcareous Marl.—Output of marl increased by 1.2% to 3.6 million tons valued at $11.4 million compared with the revised 1995 total. *(See table 2.)* Marl was produced by 11 companies with 11 quarries in 6 States. *(See table 9.)* The leading producers were, in order of tonnage, Capitol Aggregates Inc., Giant Group Ltd., and Blue Circle America, Inc.

Shell.—Shell is derived mainly from fossil reefs or oyster shell. The output of crushed shell decreased by 26.3% to 1.7 million tons valued at $6.6 million. *(See table 2.)* Crushed shell was produced by seven companies with seven operations in four States. The leading producers were, in order of tonnage, Quality Aggregates, Inc., Panther Crushing. Inc., and Leisey Shell Corp.

Granite.—The output of crushed granite increased by 3.2% to 202 million tons valued at $1.3 billion. *(See table 2.)* Crushed granite was produced by 152 companies at 326 operations with 357 quarries in 37 States.

The leading States were, in order of tonnage, Georgia, North Carolina, Virginia, South Carolina, and Arkansas; these five States accounted for 72.8% of the U.S. output. *(See table 10.)* The leading producers were, in order of tonnage, Vulcan Materials Co., Martin Marietta Aggregates, Cornerstone Construction & Materials, Inc., Blue Circle America, Inc., and Florida Rock Industries, Inc.

Traprock.—Production of crushed traprock decreased by 2.7% to 94.6 million tons valued at $572.6 million. *(See table 2.)* Traprock was produced by 256 companies at 361 operations with 559 quarries in 27 States.

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The leading States were, in order of tonnage, Oregon, Virginia, Washington, New Jersey, and California; these five States accounted for 64.4% of U.S. output. *(See table 10.)* The leading producers were, in order of tonnage, Vulcan Materials Co., Luck Stone Corp., Oldcastle Inc./Materials Group,, Stavola, Inc./Traprock Industries, and Mac Aquisitions LP DBA Meridian Aggregates.

Sandstone and Quartzite.—The combined output of crushed sandstone and quartzite increased by 7% to 37.4 million tons valued at $220.7 million. *(See table 2.)* Crushed sandstone was produced by 105 companies at 134 operations with 151 quarries in 26 States, and crushed quartzite was produced by 33 companies at 37 operations with 53 quarries in 21 States.

The leading producing States were, in order of tonnage of sandstone and quartzite, Arkansas, Pennsylvania, South Dakota, New York, and Vermont; their combined production accounted for 52.6% of the U.S. output. *(See table 10.)* The leading producers of sandstone were, in order of tonnage, Ashland Oil, Inc./Arkola Sand and Gravel Co., Martin Marietta Aggregates, and Mac Aquisitions LP DBA Meridian Aggregates Co., and the leading producers of quartzite were Nova Materials Inc., L.G. Everist Inc., and Sweetman Construction Co.

Slate.—The output of crushed slate increased by 14.2% to 2.8 million tons valued at $22.9 million. *(See table 2.)* Crushed slate was produced by 16 companies at 18 operations with 22 quarries in 12 States.

Most of the crushed slate was produced in North Carolina. The leading producers were, in order of tonnage, Martin Marietta Aggregates, Vulcan Materials Co., and Lesuer-Richmond Slate Corp.

Volcanic Cinder and Scoria.—Production of volcanic cinder and scoria increased 9.3% to 2.1 million tons valued at $13.4 million. *(See table 2.)* Volcanic cinder and scoria were produced by 22 companies from 28 operations with 77 quarries in 13 States.

The leading producing States were, in order of volume, California, New Mexico, and Arizona; their combined production accounted for 45.9% of the total U.S. output. *(See table 11.)* Leading producers were, in order of tonnage, Martin Marietta, Stoney Point Rock Quarry Inc., and Byley H.G. & Sons Construction Co., Inc.

Miscellaneous Stone.—Output of other kinds of crushed stone increased by 16.1% to 24.8 million tons valued at $147.3 million. *(See table 2.)* Miscellaneous stone was produced by 76 companies at 91 operations with 126 quarries in 24 States.

The leading producing States were, in order of volume, Pennsylvania, California, and Texas; their combined production accounted for 49.5% of the total U.S. output. *(See table 11.)*

Consumption and Uses

Crushed stone production reported to the USGS is actually material that was either sold or used by producers. Stockpiled production is not included in the reported quantities. The "sold or used" tonnage, therefore, represents the amount of production released for domestic consumption or export in a given year. Because some of the crushed stone producers did not report a breakdown by end use, their total production is included in "Unspecified, actual" use. The estimated production of nonrespondents is included in "Unspecified, estimated" use.

In 1996, U.S. consumption of crushed stone was 1.33 billion tons, a 5.3% increase compared with that of 1995. Of the 1.33 billion tons of crushed stone consumed, 551.4 million tons or 41.5% of the total was "Unspecified, actual and estimated" uses. Of the remaining 778.6 million tons reported by uses by the producers, about 83.2% was used as construction aggregates, mostly for highway and road construction and maintenance; 13.9%, for chemical and metallurgical uses, including cement and lime manufacture; 1.9%, for agricultural uses; and 0.8% for special uses and products. *(See table 13.)* To provide a more accurate estimation of the consumption patterns for crushed stone, the "Unspecified" uses are not included in the above percentages. It is recommended that in any use pattern study or marketing analysis, the quantities included in "Unspecified" uses be distributed among the reported uses by applying the above percentages to the "Unspecified" uses, total.

Limestone.—Of the 868.9 million tons of crushed limestone consumed, 341.7 million tons or 39.3%, was "Unspecified, actual and estimated" uses. Of the remaining 527.2 million tons of crushed limestone reported by uses, 77.3%, was used as construction aggregates; 19.3%, for chemical and metallurgical uses including cement and lime manufacturing; 2.3%, for agricultural uses; and 1.1% for special uses and products. *(See table 14.)*

Dolomite.—Of the 86 million tons of crushed dolomite consumed, 25.8 million tons or 30%, was "Unspecified, actual and estimated" uses. Of the remaining 60.2 million tons of crushed dolomite reported by uses, 89.7%, was used as construction aggregates; 4.4%, for chemical and metallurgical uses; 3.2%, for agricultural uses; and 2.7%, for special and miscellaneous uses. An additional undefined amount of dolomite consumed in a variety of uses, mostly construction aggregates, is reported with the limestone. *(See table 14.)*

Marble.—Of the 6.1 million tons of crushed marble consumed, 4.3 million tons, or 70.7%, was reported as "Unspecified, actual and estimated" uses. Of the remaining 1.8 million tons of crushed marble reported by uses, 1.5 million tons, or 85.8%, was used as construction aggregates; 207,000 tons, or 11.6%, as special and miscellaneous uses, including fillers and extenders; and 46,000 tons, or 2.6%, for chemical and metallurgical purposes. *(See table 16.)*

Calcareous Marl.—Of the 3.6 million tons of crushed calcareous marl consumed, 1.1 million tons or 30.2%, was reported as "Unspecified, actual and estimated" uses. Of the remaining 2.5 million tons of crushed marl reported by uses, 77.2%, was used for cement manufacturing; and most of the remaining 22.8%, as construction aggregates and for agricultural uses.

Shell.—Of the 1.7 million tons of crushed shell consumed, 86%, was used as construction aggregates; 12.8%, for cement

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manufacturing; and 1.2%, as poultry grit.

Granite.—Of the 202 million tons of crushed granite consumed, 104.4 million tons, or 51.7%, was reported as "Unspecified, actual and estimated" uses. The remaining 97.6 million tons was used as construction aggregates. *(See table 17.)*

Traprock.—Of the 94.6 million tons of crushed traprock consumed, 32.4 million tons, or 34.2%, was reported as "Unspecified, actual and estimated" uses. The remaining 62.1 million tons was used as construction aggregates. *(See table 17.)*

Sandstone and Quartzite.—Of the 27.7 million tons of crushed sandstone consumed, 16 million tons, or 57.7%, was reported as "Unspecified, actual and estimated" uses. Of the remaining 11.7 million tons of crushed sandstone reported by uses, 11.2 million tons or 95.8%, was used as construction aggregates. *(See table 18.)*

Of the 9.7 million tons of crushed quartzite consumed, 4.7 million tons or 48.3% was reported as "Unspecified, actual and estimated" uses. Of the remaining 5 million tons of crushed quartzite reported by uses, 90.1% was used as construction aggregates. *(See table 18.)*

Volcanic Cinder and Scoria.—Of the 2.1 million tons of volcanic cinder and scoria consumed, 804,000 tons or 39.2% was reported as "Unspecified, actual and estimated" uses. Most of the remaining 1.2 million tons of crushed volcanic cinder and scoria was used as construction aggregates. *(See table 19.)*

Miscellaneous Stone.—Of the 33 million tons of miscellaneous crushed stone consumed, 21.3 million tons, or 64.5%, was reported as "Unspecified, actual and estimated" uses. Of the remaining 11.7 million tons reported by uses, 8.6 million tons, or 73.5%, was used as construction aggregates, and 4.5 million tons, or 39.7%, was used for cement manufacturing. *(See table 19.)*

Recycling

As the recycling of most waste materials increases, the aggregates producers are recycling more cement concrete, and asphalt concrete materials, recovered from construction projects to produce concrete aggregates and asphalt aggregates. The annual survey of crushed stone producers now collects information on recycling of cement and asphalt concretes produced by the crushed stone producers only. No information on recycling of these materials by the construction or demolition companies is collected by the USGS.

Asphalt Concrete.—A total of 1.3 million tons of asphalt concrete valued at $8.6 million was recycled by 62 companies in 31 States. This volume represents a 14.6% decrease compared with that of 1995. *(See tables 20 and 21.)* The leading recycling States were, in descending order of tonnage, Massachusetts, Minnesota, and California. The leading recycling companies were, in order of tonnage produced, Bardon Group Inc., Oldcastle Inc./Materials Group, and Mount Hope Rock Products, Inc.

Cement Concrete.—A total of 1.2 million tons of cement concrete valued at $6.3 million was recycled by 43 companies in 16 States. This tonnage represents a 28.3% increase compared with that of 1995. *(See tables 20 and 22.)* The leading recycling States were, in descending order of tonnage, California, Massachusetts, and Wisconsin. The leading companies were, in order of tonnage produced, Dell Materials, Vulcan Materials Co., and Stoneway Concrete, Inc.

Prices

Prices in this chapter are f.o.b. plant, usually at the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs and profit.

The average unit price per ton of crushed stone increased by 1.1% to $5.40, compared with that of 1995. The average unit prices, by kind of stone, showed mostly modest increases of between 1.1% for limestone to 4.4% for traprock, as well as decreases for shell (-59%), marble (-25.7%), slate (-5.5%), and sandstone and quartzite (-1.1%). *(See table 2.)*

Transportation

For 575.1 million tons, or 43.2%, of the total 1.33 billion tons of crushed stone produced for consumption in 1996, no means of transportation was reported by the producers. Of the remaining 755 million tons of crushed stone, 571.7 million tons, or 75.7%, was reported as being transported by truck from the processing plant or quarry to the first point of sale or use; 7.8%, by rail; and 4.3%, by waterway. About 9.2% of the specified production was reported as not having been transported and, therefore, was used on-site. Information regarding means of transportation used by the producers to ship crushed stone in each geographic region is provided in table 23.

Foreign Trade

The widespread distribution of domestic crushed stone deposits and the high cost of transportation limits foreign trade to mostly local transactions across international boundaries. U.S. imports and exports are small, representing less than 1% of the domestic consumption. Shipments of crushed stone by water from Canada and especially Mexico, however, continue to increase.

Exports.—Exports of crushed stone decreased by 45.9% to 3.3 million tons compared with that of 1995, and the value decreased by only 8.4% to $36 million. About 92.7% of the exported crushed stone was limestone. Canada was the major destination with 79.7% of the total crushed stone, followed by Japan with 5.7%. *(See table 24.)*

Imports.—Imports of crushed stone increased by 4.1% to 11.3 million tons compared with that of 1995, and the value decreased by 0.8% to $89.6 million. About 88.9% of the imported crushed stone was limestone. Imports of natural calcium carbonate fines decreased from 7,000 to 3,000 tons.

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(See table 25.)

Shipments of crushed stone from the Bahamas, Canada, and Mexico into the United States continued in 1996. The imported crushed stone was used mostly as construction aggregates or for cement manufacturing. This trend is expected to continue, and the volume of imports, especially from Mexico, to increase.

Outlook

The demand for crushed stone in 1997 is expected to be about 1.38 billion tons, a 4% increase over that of 1996. Gradual increases in demand for construction aggregates are anticipated after 1997 as well, on the basis of the volume of work on the infrastructure that will be financed by the new Surface Transportation Efficiency Act and the U.S. economy in general. The projected increases will be influenced by construction activity in the public, as well as the private construction sectors.

Crushed stone f.o.b. prices are not expected to increase significantly. The delivered prices of crushed stone are, however expected to increase, especially in and near metropolitan areas, mainly because more aggregates are transported from distant sources.

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TABLE 1
SALIENT CRUSHED STONE STATISTICS 1/

(Thousand metric tons and thousand dollars)

		1992	1993	1994	1995	1996
Sold or used by producers:						
Quantity 2/		1,050,000	1,120,000	1,230,000	1,260,000	1,330,000
Value 2/		$5,590,000 e/	$5,930,000	$6,620,000	$6,740,000 r/	$7,180,000
Exports	value	$43,400	$39,300	$38,100	$39,300	$36,300
Imports 3/	do.	$60,700	$74,300	$77,800	$91,900	$91,800

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

3/ Excludes precipitated calcium carbonate.

TABLE 2
CRUSHED STONE SOLD OR USED IN THE UNITED STATES, BY KIND 1/

	1995				1996			
Kind	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value
Limestone 2/	2,007	813,000 r/	$4,060,000 r/	$4.99 r/	2,060	869,000	$4,390,000	$5.05
Dolomite	183 r/	85,100 r/	436,000 r/	5.13 r/	175	86,000	447,000	5.20
Marble	42	5,960	52,400	8.80 r/	49	6,090	42,600	7.00
Calcareous marl	13 r/	3,590 r/	10,900 r/	3.04 r/	11	3,640	11,400	3.15
Shell	11	2,320	14,300	6.18 r/	7	1,710	6,640	3.89
Granite	366 r/	196,000 r/	1,240,000 r/	6.34 r/	357	202,000	1,310,000	6.50
Traprock	589	97,200 r/	563,000 r/	5.79 r/	559	94,600	573,000	6.05
Sandstone and quartzite	253 r/	35,000 r/	208,000 r/	5.96 r/	204	37,400	221,000	5.90
Slate	18 r/	2,480 r/	21,200 r/	8.56 r/	22	2,830	22,900	8.11
Volcanic cinder and scoria	76	1,880	12,000	6.38	77	2,050	13,400	6.54
Miscellaneous stone	125 r/	21,400 r/	125,000 r/	5.83 r/	126	24,800	147,000	5.93
Total	XX	1,260,000	6,740,000 r/	5.36 r/	XX	1,330,000	7,180,000	5.40

r/ Revised. XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes limestone-dolomite reported with no distinction between the two kinds of stone.

TABLE 3
CRUSHED STONE 1/ SOLD OR USED IN THE UNITED STATES, BY REGION 2/

(Thousand metric tons and thousand dollars)

	1995		1996	
Region/Division	Quantity	Value	Quantity	Value
Northeast:				
New England	28,500	206,000	28,800	203,000
Middle Atlantic	141,000	828,000	152,000	896,000
Midwest:				
East North Central	235,000	1,070,000	249,000	1,170,000
West North Central	146,000	735,000	148,000	765,000
South:				
South Atlantic	301,000	1,810,000	319,000	1,950,000
East South Central	144,000	702,000	155,000	758,000
West South Central	142,000	649,000	145,000	647,000
West:				
Mountain	35,300	199,000	39,100	229,000
Pacific	91,000 r/	548,000 r/	93,500	573,000
Total	1,260,000	6,740,000 r/	1,330,000	7,180,000

r/ Revised.

1/ Includes volcanic cinder and scoria.

2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 4
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996,
BY QUARTER AND DIVISION 1/

Region/Division	Quantity 1st quarter (thousand metric tons)	Percentage change 2/	Quantity 2d quarter (thousand metric tons)	Percentage change 2/	Quantity 3d quarter (thousand metric tons)	Percentage change 2/	Quantity 4th quarter (thousand metric tons)	Percentage change 2/	Total 3/ (thousand metric tons)	Value total 3/ (thousands)
Northeast:										
New England	900	-49.5	7,400	-19.7	8,800	-8.3	7,200	-3.4	24,300	$174,000
Middle Atlantic	17,600	-11.3	41,700	-1.1	50,500	9.3	42,500	28.1	152,000	899,000
Midwest:										
East North Central	26,500	-10.0	66,100	1.2	88,900	13.6	68,500	10.5	250,000	1,150,000
West North Central	22,600	-9.4	40,400	8.6	48,400	3.6	39,600	10.4	151,000	759,000
South:										
South Atlantic	58,800	-5.0	88,500	8.7	88,000	4.5	82,000	14.5	317,000	1,920,000
East South Central	26,800	-2.6	42,400	13.0	47,000	12.4	39,800	10.7	156,000	710,000
West South Central	33,600	9.9	35,900	-0.7	39,300	1.4	35,200	1.3	144,000	657,000
West:										
Mountain	6,000	3.2	9,900	8.3	10,700	-1.5	8,800	-4.0	35,400	198,000
Pacific 4/	16,700	7.0	22,000	5.3	24,900	1.6	22,100	15.2	85,700	476,000
Total 5/	209,600	-3.7	354,300	4.5	406,300	6.7	345,900	11.8	1,330,000	7,110,000

1/ As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 1996 Mineral Industry Surveys."
2/ All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.
3/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and by regions.
4/ Does not include Alaska and Hawaii.
5/ Includes Alaska, Hawaii, and "Other;" see table 6.

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TABLE 5
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value
Alabama	33,600	$174,000	$5.19	38,900	$198,000	$5.09
Alaska 3/	2,430 r/ 4/	14,500 r/ 4/	5.97 r/	2,600 4/ 5/	16,500 4/ 5/	6.35
Arizona	5,520	32,600	5.91	6,800	40,600	5.97
Arkansas	25,500	169,000	6.64	26,400	158,000	5.96
California	43,700 6/ 7/	268,000 6/ 7/	6.14	46,700	295,000	6.31
Colorado	9,000	58,500	6.50	9,940	64,900	6.54
Connecticut	6,070 8/ 9/	45,500 8/ 9/	7.50	6,720	55,000	8.19
Florida	68,000	350,000	5.14	73,600 10/	394,000 10/	5.35
Georgia	60,600	373,000	6.14	63,400 6/	401,000 6/	6.33
Hawaii	7,450 11/ 12/	73,500 11/ 12/	9.87	6,560	77,500	11.82
Idaho	3,210 12/	14,000 12/	4.36	3,960 12/	20,200 12/	5.11
Illinois	61,400	335,000	5.46	66,500	364,000	5.47
Indiana	49,200 13/	234,000 13/	4.76	53,700 13/	254,000 13/	4.73
Iowa	35,300	210,000	5.96	34,400	202,000	5.88
Kansas	20,400	95,800	4.69	22,100	110,000	4.96
Kentucky	54,700	230,000	4.20	58,500 11/	243,000 11/	4.15
Louisiana	2,540 7/ 12/	26,700 7/ 12/	10.50	2,290 12/	23,900 12/	10.44
Maine	3,110	16,100	5.17	2,760	14,800	5.38
Maryland	24,200	158,000	6.54	22,400 6/ 14/	142,000 6/ 14/	6.33
Massachusetts	11,100	97,400	8.77	11,800 12/	91,600 12/	7.77
Michigan	37,500	127,000	3.38	38,600 5/ 12/	144,000 5/ 12/	3.72
Minnesota	11,300 9/ 14/	47,400 9/ 14/	4.19	12,100	59,000	4.88
Mississippi	1,990 10/	8,010 10/	4.03	2,180 10/	9,300 10/	4.26
Missouri	65,700 5/	305,000 5/	4.64	67,000	325,000	4.85
Montana	2,370 9/	9,920 9/	4.19	2,000	8,580	4.29
Nebraska	6,590	41,800	6.34	6,370	39,800	6.25
Nevada	2,410	21,400	8.90	3,080	25,200	8.18
New Hampshire	2,150 15/	9,150 15/	4.25	1,430 15/	8,650 15/	6.06
New Jersey	21,000	132,000	6.28	21,400	145,000	6.79
New Mexico	3,660	18,800	5.12	3,480 9/ 14/	18,800 9/ 14/	5.42
New York	39,500	204,000	5.15	43,600	233,000	5.34
North Carolina	57,300	384,000	6.69	57,200	394,000	6.89
Ohio	60,900	265,000	4.35	63,600	291,000	4.57
Oklahoma	31,100 7/	125,000 7/ 14/	4.02	28,300 7/ 14/	117,000 7/ 14/	4.14
Oregon	20,700	95,700	4.63	22,000	102,000	4.65
Pennsylvania	80,900	492,000	6.09	87,400	518,000	5.92
Rhode Island	1,250	9,140	7.30	1,440	9,680	6.74
South Carolina	22,000	132,000	5.98	23,800	146,000	6.15
South Dakota	5,420 5/ 12/	25,700 5/ 12/	4.74	5,640	28,700	5.09
Tennessee	52,600	286,000	5.43	55,100	305,000	5.53
Texas	81,100	310,000	3.82	86,500	341,000	3.94
Utah	4,140	14,800	3.58	4,380	19,100	4.35
Vermont	4,420	20,700	4.68	4,560	22,800	5.01
Virginia	55,400	326,000	5.89	59,700	351,000	5.87
Washington	15,800 4/ 6/	76,800 4/ 6/	4.85	15,400	81,400	5.27
West Virginia	11,800 8/	75,000 8/	6.38	12,700 8/	78,400 8/	6.16
Wisconsin	26,000	108,000	4.16	26,000	113,000	4.34
Wyoming	4,670	27,500	5.88	5,180	30,000	5.79
Other	6,620	69,300	10.47	9,400	53,000	5.64
Total	1,260,000	6,740,000 r/	5.34 r/	1,330,000	7,180,000	5.40

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."

3/ Data derived, in part, from the Alaska Division of Geological and Geophysical Surveys information.

4/ Excludes limestone-dolomite.

5/ Excludes granite.

6/ Excludes marble.

7/ Excludes shell.

8/ Excludes dolomite.

9/ Excludes quartzite.

10/ Excludes calcareous marl.

11/ Excludes sandstone.

12/ Excludes other.

13/ Excludes slate.

14/ Excludes traprock.

15/ Excludes limestone.

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TABLE 6
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996,
BY QUARTER AND STATE 1/

State	Quantity 1st quarter (thousand metric tons)	Percentage change 2/	Quantity 2d quarter (thousand metric tons)	Percentage change 2/	Quantity 3d quarter (thousand metric tons)	Percentage change 2/	Quantity 4th quarter (thousand metric tons)	Percentage change 2/	Total 3/ (thousand metric tons)	Value total 3/ (thousands)
Alabama	7,800	6.6	10,700	19.2	10,700	15.5	9,700	20.9	38,900	$204,000
Alaska 4/ 5/	--	--	--	--	--	--	--	--	3,500	21,500
Arizona 6/	--	--	--	--	--	--	--	--	5,250	31,200
Arkansas	5,500	2.9	7,000	4.8	7,300	1.1	6,500	4.8	26,400	177,000
California 5/	8,900	16.8	11,800	8.0	14,100	-1.0	11,900	8.6	46,700	289,000
Colorado	1,300	-9.3	3,100	51.6	3,000	-1.7	2,500	3.2	9,950	65,100
Connecticut 5/	100	-71.5	1,800	-4.2	2,300	10.1	1,100	-35.4	5,310	40,100
Delaware 4/	--	--	--	--	--	--	--	--	--	--
Florida	18,000	-3.2	18,000	4.3	17,700	9.3	17,700	10.5	71,300	371,000
Georgia	12,600	-2.0	18,600	13.5	17,500	2.9	15,600	9.0	64,300	399,000
Hawaii 4/ 5/	--	--	--	--	--	--	--	--	7,700	76,200
Idaho 5/ 6/	300	-31.8	300	-54.0	800	-18.4	700	-35.6	2,120	9,340
Illinois	7,100	-7.5	16,600	4.9	23,500	12.7	19,200	13.0	66,500	365,000
Indiana 5/	7,200	-4.7	13,400	5.2	19,400	23.8	14,600	10.3	54,600	262,000
Iowa	4,400	-6.6	10,000	-4.0	11,900	0.6	9,100	8.5	35,400	212,000
Kansas	4,200	4.4	6,300	22.0	6,400	4.3	6,400	28.3	23,400	111,000
Kentucky 5/	10,100	-7.3	14,900	13.5	19,400	20.7	14,900	1.3	59,200	252,000
Louisiana 5/ 6/	--	--	--	--	--	--	--	--	2,650	27,900
Maine	300	4.8	900	8.2	1,100	5.1	800	-9.1	3,160	16,400
Maryland	3,500	-21.0	7,300	6.3	7,900	9.8	7,700	34.5	26,400	174,000
Massachusetts	200	-64.5	2,700	-32.3	3,000	-15.5	3,100	6.3	9,020	79,400
Michigan	2,600	2.0	11,200	-4.3	13,700	6.3	11,400	10.1	38,900	132,000
Minnesota 5/	500	-6.9	3,400	8.9	5,300	16.0	2,900	-4.6	12,100	51,500
Mississippi 5/ 6/	--	--	--	--	--	--	--	--	2,300	9,300
Missouri 5/	12,300	-15.4	17,200	14.3	19,400	-0.7	18,100	9.2	67,000	315,000
Montana 5/ 6/	--	--	--	--	--	--	--	--	2,290	9,720
Nebraska	1,000	-14.6	1,900	12.3	2,000	-7.2	1,700	15.2	6,680	42,800
Nevada	500	1.2	600	-7.6	700	17.0	600	-13.3	2,370	21,200
New Hampshire 5/	90	-39.3	500	-1.6	800	-4.6	600	-8.6	1,990	8,570
New Jersey	2,200	-34.2	5,700	-7.2	6,500	4.8	6,800	28.2	21,200	134,000
New Mexico	600	-7.9	1,200	45.3	900	-29.5	700	-28.5	3,350	17,200
New York	3,400	-11.9	11,300	2.4	17,000	14.6	11,900	21.9	43,600	227,000
North Carolina	9,900	-7.6	16,700	8.9	16,300	-4.2	15,600	10.0	58,600	395,000
North Dakota 4/	--	--	--	--	--	--	--	--	--	--
Ohio	7,000	-18.4	18,000	1.5	22,300	13.2	16,200	9.5	63,600	280,000
Oklahoma 5/	6,700	3.3	7,600	-6.0	8,000	-9.3	7,200	-6.6	29,500	119,000
Oregon	4,500	-0.8	6,400	12.3	5,900	1.1	5,200	10.5	21,900	102,000
Pennsylvania	12,100	-5.1	24,700	-1.3	26,800	7.0	23,800	31.7	87,400	538,000
Rhode Island 6/	--	--	--	--	--	--	--	--	1,100	8,090
South Carolina	4,800	3.1	6,600	9.8	6,500	11.9	5,800	6.1	23,800	143,000
South Dakota 5/	500	-8.0	1,300	-15.5	2,600	31.8	1,300	-9.2	5,630	27,000

See footnotes at end of table.

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TABLE 6 --Continued
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996,
BY QUARTER AND STATE 1/

State	Quantity 1st quarter (thousand metric tons)	Percentage change 2/	Quantity 2d quarter (thousand metric tons)	Percentage change 2/	Quantity 3d quarter (thousand metric tons)	Percentage change 2/	Quantity 4th quarter (thousand metric tons)	Percentage change 2/	Total 3/ (thousand metric tons)	Value total 3/ (thousands)
Tennessee	8,100	-9.7	15,700	7.8	16,800	4.4	14,600	11.7	55,100	$245,000
Texas	20,900	14.3	20,600	-0.8	23,700	7.8	21,200	5.8	86,400	333,000
Utah	900	12.1	800	-23.6	1,100	-6.1	1,100	8.0	4,000	14,400
Vermont 5/	--	--	--	--	--	--	--	--	4,560	21,400
Virginia	8,900	-8.4	16,700	5.1	17,900	7.9	16,300	23.0	59,700	352,000
Washington 6/	3,400	-13.1	3,700	-18.4	4,700	18.5	5,400	61.5	17,200	84,500
West Virginia 6/	2,100	14.0	4,000	18.2	4,200	5.4	3,500	42.3	14,000	89,300
Wisconsin	2,400	-22.0	6,500	-7.9	10,000	6.3	6,900	7.5	25,800	108,000
Wyoming	700	45.3	1,600	-5.5	1,700	15.0	1,100	3.5	5,050	29,800
Other	--	--	--	--	--	--	--	--	7,000	73,500
Total 3/	XX	XX	XX	XX	XX	XX	XX	XX	1,330,000	7,110,000

XX Not applicable.
1/ As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 1996 Mineral Industry Surveys."
2/ All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.
3/ Data may not add to totals shown because of independent rounding and differences between projected totals by States and by regions.
4/ State not included in quarterly survey.
5/ Owing to low number of companies, no production estimates by quarter were generated.
6/ To avoid disclosing proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."

TABLE 7
CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 1996,
BY REGION AND SIZE OF OPERATION 1/

Size range (metric tons)	Northeast				Midwest				South			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	41	9.0	277	(2/)	174	15.0	1,720	(2/)	57	5.0	533	(2/)
25,000 to 49,999	24	5.0	742	(2/)	106	9.0	3,610	(2/)	40	4.0	1,380	(2/)
50,000 to 99,999	34	7.0	2,410	1.0	154	14.0	10,300	2.0	82	8.0	5,750	(2/)
100,000 to 199,999	53	12.0	7,140	3.0	160	14.0	21,300	5.0	132	13.0	18,100	2.0
200,000 to 299,999	60	13.0	13,600	7.0	114	10.0	26,000	6.0	83	8.0	18,900	3.0
300,000 to 399,999	49	11.0	15,700	8.0	64	5.0	20,100	5.0	71	7.0	22,600	3.0
400,000 to 499,999	36	8.0	14,800	8.0	60	5.0	23,900	6.0	81	8.0	33,000	5.0
500,000 to 599,999	27	6.0	13,100	7.0	51	4.0	25,300	6.0	78	7.0	38,900	6.0
600,000 to 699,999	19	4.0	11,200	6.0	36	3.0	21,300	5.0	46	4.0	27,200	4.0
700,000 to 799,999	25	5.0	17,100	9.0	31	2.0	21,100	5.0	46	4.0	31,800	5.0
800,000 to 899,999	14	3.0	10,800	6.0	24	2.0	18,600	4.0	37	3.0	28,400	4.0
900,000 to 999,999	6	1.0	5,170	2.0	20	1.0	17,500	4.0	35	3.0	30,300	4.0
1,000,000 to 1,499,999	34	7.0	38,100	21.0	58	5.0	63,500	16.0	106	10.0	119,000	19.0

See footnotes at end of table.

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TABLE 7--Continued
CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 1996,
BY REGION AND SIZE OF OPERATION 1/

Size range (metric tons)	Northeast				Midwest				South			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
1,500,000 to 1,999,999	11	2.0	17,500	9.0	22	2.0	34,700	8.0	48	4.0	72,700	11.0
2,000,000 to 2,499,999	1	(2/)	1,920	1.0	10	(2/)	18,800	4.0	24	2.0	47,300	7.0
2,500,000 to 4,999,999	4	(2/)	11,700	6.0	13	1.0	38,900	9.0	23	2.0	66,200	10.0
5,000,000 and over	--	--	--	--	5	(2/)	30,100	7.0	7	(2/)	57,600.	9.0
Total	438	100.0	181,000	100.0	1102	100.0	397,000	100.0	996	100.0	620,000	100.0

Size range (metric tons)	West				U.S. total			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	159	27.0	1,450	1.0	431	13.0	3,980	(2/)
25,000 to 49,999	69	11.0	2,260	1.0	239	7.0	7,980	(2/)
50,000 to 99,999	92	15.0	6,180	4.0	362	11.0	24,700	1.0
100,000 to 199,999	83	14.0	10,500	8.0	428	13.0	57,000	4.0
200,000 to 299,999	57	9.0	13,100	9.0	314	10.0	71,600	5.0
300,000 to 399,999	26	4.0	8,180	6.0	210	6.0	66,600	5.0
400,000 to 499,999	16	2.0	6,510	4.0	193	6.0	78,100	5.0
500,000 to 599,999	16	2.0	8,010	6.0	172	5.0	85,300	6.0
600,000 to 699,999	13	2.0	7,730	5.0	114	3.0	67,500	5.0
700,000 to 799,999	7	1.0	4,700	3.0	109	3.0	74,700	5.0
800,000 to 899,999	3	(2/)	2,330	1.0	78	2.0	60,100	4.0
900,000 to 999,999	9	1	7,950	6.0	70	2.0	61,000	4.0
1,000,000 to 1,499,999	14	2.0	14,900	11.0	212	6.0	235,000	17.0
1,500,000 to 1,999,999	7	1.0	10,800	8.0	88	2.0	136,000	10.0
2,000,000 to 2,499,999	4	(2/)	8,320	6.0	39	1.0	76,300	5.0
2,500,000 to 4,999,999	6	1	19,600	14.0	46	1.0	137,000	10.0
5,000,000 and over	--	--	--	--	12	(2/)	87,700	6.0
Total	581	100.0	133,000	100.0	3117	100.0	1,330,000	100.0

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

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TABLE 8
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Alabama	34,800 2/	176,000 2/	W	W
Alaska 3/	W 2/	W 2/	--	--
Arizona	4,110	23,000	--	--
Arkansas	7,260	36,700	W	W
California	24,900	145,000	384	2,670
Colorado	2,840	15,200	--	--
Connecticut	W	W	W	W
Florida	71,000 2/	379,000 2/	W	W
Georgia	10,100 2/	65,600 2/	--	--
Hawaii	1,030	10,500	--	--
Idaho	1,370	7,920	--	--
Illinois	57,700 2/	319,000 2/	8,800	45,000
Indiana	46,500 2/	217,000 2/	7,170	37,400
Iowa	34,400 2/	202,000 2/	42	169
Kansas	21,400 2/	108,000 2/	--	--
Kentucky	58,500	243,000	--	--
Maine	1,410	7,410	--	--
Maryland	17,400	111,000	--	--
Massachusetts	2,140 2/	23,500 2/	--	--
Michigan	30,300	115,000	8,330	29,100
Minnesota	8,210	38,800	802	3,480
Mississippi	W	W	--	--
Missouri	63,300 2/	305,000 2/	2,590	13,000
Montana	1,540	6,240	--	--
Nebraska	6,370	39,800	--	--
Nevada	2,170	15,600	W	W
New Hampshire	W	W	--	--
New Jersey	W	W	--	--
New Mexico	1,350	6,090	--	--
New York	27,600 2/	136,000 2/	7,880	50,900
North Carolina	6,250	43,200	251	1,720
Ohio	48,200 2/	226,000 2/	15,400	63,900
Oklahoma	21,000	82,800	2,990	12,600
Oregon	W	W	--	--
Pennsylvania	55,200 2/	318,000 2/	10,800	66,900
Rhode Island	W	W	--	--
South Carolina	3,740	18,300	--	--
South Dakota	2,850	11,500	--	--
Tennessee	49,500	275,000	W	W
Texas	82,500	323,000	W	W
Utah	1,480 2/	8,500 2/	W	W
Vermont	2,260	8,440	W	W
Virginia	16,500 2/	94,600 2/	4,480	30,900
Washington	2,140 2/	21,900 2/	W	W
West Virginia	11,900	72,400	W	W
Wisconsin	20,800 2/	92,600 2/	263	1,400
Wyoming	1,620 2/	5,330 2/	--	--
Other	5,160 2/	31,100 2/	15,800	88,400
Total	869,000	4,390,000	86,000	447,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes limestone-dolomite reported with no distinction between the two kinds of stone.

3/ Data derived in part from the Alaska Division of Geological and Geophysical Surveys information

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TABLE 9
CRUSHED CALCAREOUS MARL AND MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Calcareous marl		Marble	
	Quantity	Value	Quantity	Value
Michigan	7	20	--	--
New York	--	--	80	1,380
Pennsylvania	--	--	464	2,860
Vermont	--	--	1,030	4,610
Wyoming	--	--	91	3,230
Other	3,630 2/	11,400 2/	4,420 3/	30,600 3/
Total	3,640	11,400	6,090	42,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes data for Florida, Mississippi, North Carolina, South Carolina, and Texas.
3/ Includes data for Alabama, Arizona, California, Georgia, Maryland, South Carolina, and Texas.

TABLE 10
CRUSHED GRANITE, TRAPROCK, AND SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	Granite		Traprock		Sandstone and quartzite	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	--	--	--	--
Alaska 2/	W	W	888	3,300	--	--
Arizona	1,540	8,580	--	--	W	W
Arkansas	9,720	75,100	--	--	8,030	39,800
California	5,490	33,600	7,940	58,700	854	5,590
Colorado	5,590	39,500	204	W	W	W
Connecticut	144	1,110	4,580	W	W	W
Georgia	53,300	336,000	--	--	--	--
Hawaii	W	W	4,220	55,100	W	W
Idaho	549	3,060	1,680	6,150	W	W
Kansas	W	W	--	--	W	W
Kentucky	--	--	--	--	W	W
Louisiana	--	--	--	--	W	W
Maine	W	W	W	W	W	W
Maryland	4,880	29,500	W	W	196	1,110
Massachusetts	3,200	24,600	6,450	43,500	--	--
Michigan	W	W	--	--	7	120
Minnesota	W	W	W	W	944	W
Missouri	W	W	W	W	W	W
Montana	--	--	W	W	W	W
Nevada	W	W	W	W	--	--
New Hampshire	779	3,890	649	W	--	--
New Jersey	9,330	75,500	9,690	56,100	W	W
New Mexico	1,490	W	W	224	W	W
New York	3,560	19,200	W	W	1,740	8,830
North Carolina	42,400	289,000	4,500	31,300	W	W
Ohio	--	--	--	--	42	W
Oklahoma	W	W	W	W	W	W
Oregon	70	306	19,700	91,000	389	1,770
Pennsylvania	4,030	25,800	2,810	22,400	6,020	35,500
Rhode Island	948	6,680	W	W	--	--
South Carolina	17,700	119,000	--	--	--	--
South Dakota	1	7	--	--	2,790	17,200
Tennessee	W	W	--	--	W	W
Texas	W	W	W	W	746	W
Utah	W	W	--	--	113	W
Vermont	W	W	--	--	1,120	8,600
Virginia	24,000	138,000	12,500	71,900	W	W
Washington	257	1,310	11,000	49,000	W	3,290
West Virginia	--	--	--	--	851	5,970
Wisconsin	1,350	2,690	W	W	W	W
Wyoming	W	W	W	W	W	W
Other	11,700	80,300	7,710	83,900	13,600	92,900
Total	202,000	1,310,000	94,600	573,000	37,400	221,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Data derived, in part, from the Alaska Division of Geological and Geophysical Surveys information.

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TABLE 11
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE 1/ SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY STATE 2/

(Thousand metric tons and thousand dollars)

State	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Alabama	--	--	W	W
Alaska 3/	--	--	1,720	13,200
Arizona	238	W	W	W
Arkansas	--	--	35	W
California	420	3,450	6,490	43,900
Colorado	W	W	W	W
Connecticut	--	--	W	W
Florida	--	--	1,800	7,840
Hawaii	W	W	W	W
Idaho	--	--	W	W
Indiana	--	--	W	W
Louisiana	--	--	W	W
Maine	--	--	W	W
Massachusetts	--	--	W	W
Michigan	--	--	W	W
Mississippi	--	--	W	W
Montana	3	9	--	--
Nevada	W	W	W	W
New Jersey	--	--	W	W
New Mexico	283	2,170	W	1,350
New York	--	--	1,560	7,000
North Carolina	W	W	W	W
Oklahoma	--	--	W	W
Oregon	35	221	838	3,740
Pennsylvania	--	--	8,040	45,700
South Carolina	--	--	W	W
Tennessee	--	--	W	W
Texas	W	W	1,810	4,230
Utah	W	W	--	--
Vermont	--	--	W	W
Virginia	--	--	995	8,940
Washington	W	W	919	4,150
Wyoming	W	W	--	--
Other	1,070	7,570	8,820	47,500
Total	2,050	13,400	33,000	188,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Includes marl, shell, slate, and other stone.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Data derived, in part, from the Alaska Division of Geological and Geophysical Surveys information.

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TABLE 12
KIND OF CRUSHED STONE PRODUCED IN THE UNITED STATES IN 1996, BY STATE

State	Lime-stone	Dolo-mite	Marble	Marl	Shell	Granite	Trap-rock	Sand-stone	Quartzite	Slate	Volcanic cinder and scoria	Miscella-neous
Alabama	X	X	X			X				X		
Alaska 1/	X					X	X			X		X
Arizona	X		X			X		X	X		X	X
Arkansas	X	X				X		X	X			X
California	X	X	X		X	X	X	X	X	X	X	X
Colorado	X					X	X	X	X		X	X
Connecticut	X	X				X	X		X			X
Florida	X	X		X	X							
Georgia	X		X			X						
Hawaii	X					X	X	X			X	X
Idaho	X					X	X		X			X
Illinois	X	X										
Indiana	X	X								X		
Iowa	X	X										
Kansas	X					X		X	X			
Kentucky	X							X				
Louisiana								X				X
Maine	X					X	X		X	X		X
Maryland	X		X			X	X	X				
Massachusetts	X					X	X					X
Michigan	X	X		X		X		X				X
Minnesota	X	X				X	X	X	X			
Mississippi	X			X								
Missouri	X	X				X	X	X	X			
Montana	X						X	X	X		X	
Nebraska	X											
Nevada	X	X				X	X				X	X
New Hampshire	X					X	X					
New Jersey	X					X	X	X				X
New Mexico	X					X	X		X		X	X
New York	X	X	X			X	X	X		X		X
North Carolina	X	X		X		X	X		X	X	X	X
Ohio	X	X						X				
Oklahoma	X	X			X	X	X	X		X		X
Oregon	X				X	X	X	X	X	X	X	X
Pennsylvania	X	X	X			X	X	X	X			X
Rhode Island	X					X	X					
South Carolina	X		X	X		X						
South Dakota	X					X			X			
Tennessee	X	X				X		X				X
Texas	X	X	X	X		X	X	X			X	X
Utah	X	X				X		X	X		X	
Vermont	X	X	X			X			X	X		
Virginia	X	X				X	X	X	X	X		X
Washington	X	X				X	X	X		X	X	X
West Virginia	X	X						X				
Wisconsin	X	X				X	X	X	X			
Wyoming	X		X			X	X		X		X	

1/ Data derived, in part, from the Alaska Division of Geological and Geophysical Surveys.

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TABLE 13
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY USE 1/

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Coarse aggregate (+1 1/2 inch):			
Macadam	4,160	$24,400	$5.86
Riprap and jetty stone	17,500	109,000	6.21
Filter stone	7,280	43,000	5.91
Other coarse aggregate	5,890	34,800	5.91
Coarse aggregate, graded:			
Concrete aggregate, coarse	99,000	578,000	5.84
Bituminous aggregate, coarse	88,900	516,000	5.81
Bituminous surface-treatment aggregate	22,900	147,000	6.40
Railroad ballast	13,000	78,700	6.04
Other graded coarse agggregate	26,100	173,000	6.64
Fine aggregate (-3/8 inch):			
Stone sand, concrete	20,100	128,000	6.38
Stone sand, bituminous mix or seal	25,500	140,000	5.47
Screening, undesignated	22,700	112,000	4.92
Other fine aggregate	5,330	31,000	5.82
Coarse and fine aggregates:			
Graded road base or subbase	176,000	802,000	4.56
Unpaved road surfacing	34,100	161,000	4.73
Terrazzo and exposed aggregate	2,680	19,900	7.43
Crusher run or fill or waste	44,400	213,000	4.80
Other coarse and fine aggregates	21,900	113,000	5.16
Roofing granules	2,450	31,600	12.93
Other construction materials 2/	8,120	45,200	5.57
Agricultural:			
Agricultural limestone	12,300	69,600	5.64
Poultry grit and mineral food	1,320	13,300	10.12
Other agricultural uses	986	6,840	6.94
Chemical and metallurgical:			
Cement manufacture	83,500	309,000	3.70
Lime manufacture	13,600	67,700	4.98
Dead-burned dolomite manufacture	691	4,540	6.58
Flux stone	6,230	34,600	5.55
Chemical stone	765	4,070	5.33
Glass manufacture	450	4,800	10.66
Sulfur oxide removal	2,750	13,800	5.03
Special:			
Mine dusting or acid water treatment	412	7,800	18.92
Asphalt fillers or extenders	1,280	10,500	8.20
Whiting or whiting substitute	801	22,100	27.56
Other fillers or extenders	3,450	84,100	24.41
Other miscellaneous uses:			
Light weight aggregate (slate)	669	7,080	10.58
Other specified uses not listed 3/	1,630	21,000	12.92
Unspecified: 4/			
Actual	370,000	2,090,000	5.65
Estimated	182,000	913,000	5.02
Total	1,330,000	7,180,000	5.40

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes building products, drain fields, pipe bedding and waste material.
3/ Includes flour (slate), paper manufacture, and sugar refining.
4/ Includes production reported without a breakdown by end use and estimates for nonrespondents.

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TABLE 14
CRUSHED LIMESTONE 1/ AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY USE 2/

(Thousand metric tons and thousand dollars)

Use	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Coarse aggregate (+1 1/2 inch):				
Macadam	3,190	18,300	346	2,120
Riprap and jetty stone	10,700	57,500	999	6,020
Filter stone	4,330	22,500	174	1,040
Other coarse aggregate	3,930	21,600	398	2,470
Coarse aggregate, graded:				
Concrete aggregate, coarse	67,000	363,000	8,970	46,900
Bituminous aggregate, coarse	59,000	325,000	7,760	41,700
Bituminous aggregate, fine	12,800	70,900	2,050	12,300
Railroad ballast	2,830	15,200	1,340	6,060
Other graded coarse aggregate	15,200	90,500	3,060	18,800
Fine aggregate (-3/8 inch):				
Stone sand, concrete	13,500	80,100	832	5,790
Stone sand, bituminous mix or seal	13,700	71,200	2,930	16,500
Screening, undesignated	13,600	61,400	1,580	9,780
Other fine aggregate	4,110	23,600	313	1,500
Coarse and fine aggregates:				
Graded road base or subbase	117,000	493,000	13,400	59,500
Unpaved road surfacing	20,700	100,000	5,810	27,400
Terrazzo and exposed aggregate	1,370	7,490	40	313
Crusher run or fill or waste	24,700	110,000	2,810	11,700
Other coarse and fine aggregates	14,700	67,000	773	4,330
Roofing granules	223	1,360	(3/)	(3/)
Other construction materials	5,020 4/	26,400 4/	416 5/	2,420 5/
Agricultural:				
Agricultural limestone	10,600	57,100	1,750	12,500
Poultry grit and mineral food	1,120	11,800	W	W
Other agricultural uses	567	3,430	201	2,220
Chemical and metallurgical:				
Cement manufacture	80,800	301,000	W	W
Lime manufacture	12,200	59,500	1,310	7,180
Dead-burned dolomite manufacture	502	3,650	W	W
Flux stone	4,590	26,900	1,330	4,380
Chemical stone	765	4,070	--	--
Glass manufacture	W	W	W	W
Sulfur oxide removal	2,730	13,800	12	39
Special:				
Mine dusting or acid water treatment	387	7,120	W	W
Asphalt fillers or extenders	1,000	7,850	W	W
Whiting or whiting substitute	784	21,500	W	W
Other fillers or extenders	2,640	74,100	363	6,190
Other specified uses not listed	878 6/	15,200 6/	1,240	10,200
Unspecified: 7/				
Actual	214,000	1,120,000	20,600	104,000
Estimated	128,000	637,000	5,170	24,100
Total	869,000	4,390,000	86,000	447,000

W Withheld to avoid disclosing company proprietary data; included with "Other specified uses not listed."
1/ Includes a minor amount of limestone-dolomite reported without a distinction between the two.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Included with "Other construction materials."
4/ Includes building products, drain fields, pipe bedding, and waste material.
5/ Includes drain fields and waste material.
6/ Includes paper manufacture and sugar refining.
7/ Includes production reported without a breakdown by end use and estimates for nonrespondents.

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TABLE 15
CRUSHED LIMESTONE 1/ AND DOLOMITE SOLD OR USED BY PRODUCERS
IN 1996, BY STATE AND USE 2/

(Thousand metric tons and thousand dollars)

State	Concrete aggregate		Bituminous aggregate		Roadstone and coverings		Riprap and railroad ballast		Other construction uses	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	3,470	16,400	6,510	32,100	3,570	16,500	452	2,220	3,750	18,500
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	W	W	--	--	W	W
Arkansas	618	3,240	379	2,040	1,970	9,880	131	791	777	3,790
California	2,010	12,000	1,530	10,900	1,170	5,680	305	2,540	378	1,090
Colorado	W	W	--	--	--	--	--	--	--	--
Connecticut	W	W	W	W	W	W	--	--	W	W
Florida	19,600	136,000	9,710	62,500	16,000	63,000	256	1,380	9,470	33,700
Georgia	1,120	7,170	1,790	12,300	700	4,100	92	734	1,020	6,200
Hawaii	W	W	--	--	W	W	--	--	11	206
Idaho	--	--	--	--	--	--	--	--	--	--
Illinois	7,340	39,800	7,160	43,100	13,800	63,000	1,120	7,200	2,890	14,000
Indiana	5,640	21,600	7,450	25,700	8,290	39,500	1,560	7,060	2,110	9,410
Iowa	1,150	6,360	663	3,880	5,390	26,500	201	1,440	498	1,960
Kansas	1,000	6,730	1,030	6,470	2,400	11,400	113	813	2,450	12,300
Kentucky	3,850	18,600	8,190	40,300	7,220	32,100	768	3,960	2,780	13,900
Maine	145	W	W	W	--	--	W	W	W	W
Maryland	365	2,320	548	3,300	W	W	175	1,140	2,190	8,640
Massachusetts	--	--	W	W	W	W	W	W	246	3,170
Michigan	1,910	6,100	1,500	6,940	2,810	11,500	195	1,520	563	2,040
Minnesota	585	3,880	W	W	2,680	11,700	192	1,310	634	3,750
Mississippi	--	--	W	W	--	--	--	--	W	W
Missouri	3,560	20,300	6,220	44,400	11,800	49,600	2,950	10,300	2,170	8,820
Montana	W	W	--	--	W	W	--	W	W	W
Nebraska	842	6,130	416	2,190	424	3,270	135	1,280	528	3,670
Nevada	W	W	112	W	W	W	--	W	W	W
New Hampshire	W	W	--	--	--	--	W	W	--	--
New Jersey	--	--	--	--	--	--	--	--	--	--
New Mexico	W	W	23	66	111	474	W	W	35	155
New York	2,620	18,300	6,640	46,000	4,890	31,000	414	2,770	4,400	22,800
North Carolina	103	691	W	W	188	1,060	33	254	244	1,500
Ohio	5,710	23,400	4,580	20,000	16,900	69,500	1,110	4,680	2,180	11,300
Oklahoma	2,390	11,800	457	2,640	1,650	5,720	89	538	2,420	8,470
Oregon	--	--	--	--	--	--	--	--	--	--
Pennsylvania	4,780	28,100	14,000	83,600	11,600	61,800	1,270	8,860	7,410	39,100
Rhode Island	--	--	--	--	--	--	--	--	--	W
South Carolina	--	--	--	--	W	W	--	--	--	--
South Dakota	W	W	W	W	W	W	W	W	W	W
Tennessee	2,630	16,400	12,700	72,900	12,300	63,500	1,580	8,190	6,520	34,800
Texas	15,300	67,300	14,000	69,500	21,700	66,400	819	4,460	6,890	26,900
Utah	--	--	W	W	796	2,380	W	W	W	W
Vermont	--	--	--	--	--	--	--	--	--	--
Virginia	2,530	15,900	3,100	18,900	3,690	18,100	635	4,330	2,920	14,600
Washington	--	--	--	--	--	--	W	W	W	W
West Virginia	667	3,970	1,240	6,930	599	3,330	456	2,380	1,340	6,760
Wisconsin	1,400	7,260	670	3,420	8,120	34,200	135	777	1,250	4,730
Wyoming	W	W	W	W	W	W	W	W	W	W
Total	91,300	500,000	111,000	620,000	161,000	705,000	15,200	80,900	68,100	316,000
Total withheld	1,220	10,200	2,930	14,000	3,330	13,300	223	1,350	1,590	11,100
Grand total	92,500	510,000	114,000	634,000	164,000	718,000	15,400	82,300	69,700	327,000

See footnotes at end of table.

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TABLE 15--Continued
CRUSHED LIMESTONE 1/ AND DOLOMITE SOLD OR USED BY PRODUCERS
IN 1996, BY STATE AND USE 2/

(Thousand metric tons and thousand dollars)

State	Cement manufacture		Agricultural uses		Lime manufacture		Other uses		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	190	1,330	320	W	16,500	89,000	34,800	176,000
Alaska	--	--	--	--	--	--	W	W	W	W
Arizona	W	W	W	W	W	W	4,110	23,000	4,110	23,000
Arkansas	W	W	166	965	W	W	3,220	16,000	7,260	36,700
California	11,400	42,100	118	1,810	--	--	8,440	71,600	25,300	148,000
Colorado	1,160	5,320	--	--	--	--	1,680	9,880	2,840	15,200
Connecticut	--	--	W	W	--	--	W	W	W	W
Florida	3,220	9,160	463	2,220	--	--	12,300	71,300	71,000	379,000
Georgia	W	W	13	92	--	--	5,390	34,900	10,100	65,600
Hawaii	162	1,440	W	W	--	--	855	8,860	1,030	10,500
Idaho	W	W	632	1,830	W	W	732	6,100	1,370	7,920
Illinois	2,360	9,080	2,580	12,600	--	--	29,300	175,000	66,500	364,000
Indiana	3,530	9,270	1,510	7,840	W	W	23,600	134,000	53,700	254,000
Iowa	3,070	22,900	672	2,890	--	--	22,800	136,000	34,400	202,000
Kansas	1,940	7,710	216	939	--	--	12,300	61,600	21,400	108,000
Kentucky	W	W	974	4,170	W	W	34,700	130,000	58,500	243,000
Maine	W	W	8	W	W	W	W	7,410	1,410	7,410
Maryland	W	W	--	W	--	--	14,100	96,000	17,400	111,000
Massachusetts	--	--	W	W	W	W	1,890	20,300	2,140	23,500
Michigan	4,430	20,800	111	779	W	W	27,100	94,000	38,600	144,000
Minnesota	--	--	199	1,070	W	W	4,720	20,600	9,010	42,300
Mississippi	--	--	W	W	--	--	W	W	W	W
Missouri	8,510	27,900	1,250	5,970	1,200	5,120	28,200	145,000	65,900	318,000
Montana	W	W	--	--	--	--	1,540	6,240	1,540	6,240
Nebraska	W	W	316	2,740	--	--	3,710	20,500	6,370	39,800
Nevada	--	--	W	W	W	W	2,170	15,600	2,170	15,600
New Hampshire	--	--	--	--	--	--	W	W	W	W
New Jersey	--	--	--	--	--	--	W	W	W	W
New Mexico	W	W	--	--	--	--	1,190	5,390	1,350	6,090
New York	3,810	15,000	80	705	--	--	12,600	50,500	35,500	187,000
North Carolina	--	--	W	W	--	--	5,930	41,400	6,500	44,900
Ohio	W	W	1,110	6,370	324	W	31,700	155,000	63,600	290,000
Oklahoma	W	W	138	527	--	--	16,800	65,700	24,000	95,400
Oregon	W	W	--	--	--	--	W	W	W	W
Pennsylvania	6,080	29,000	627	6,040	1,250	8,940	18,900	120,000	66,000	385,000
Rhode Island	--	--	W	W	--	--	W	W	W	W
South Carolina	--	--	--	--	--	--	3,740	18,300	3,740	18,300
South Dakota	982	W	--	--	W	W	W	W	2,850	11,500
Tennessee	W	W	583	4,780	W	W	13,200	74,100	49,500	275,000
Texas	8,830	21,200	505	3,260	1,000	5,000	13,500	59,100	82,500	323,000
Utah	W	W	W	W	W	W	1,480	8,500	1,480	8,500
Vermont	--	--	--	--	--	--	2,260	8,440	2,260	8,440
Virginia	W	W	774	8,180	796	4,280	6,550	41,300	21,000	126,000
Washington	W	W	W	W	W	W	2,140	21,900	2,140	21,900
West Virginia	1,120	W	8	67	--	--	6,440	49,000	11,900	72,400
Wisconsin	--	--	387	4,100	W	W	9,150	39,500	21,100	94,000
Wyoming	--	--	--	--	--	--	1,620	5,330	1,620	5,330
Total	60,600	221,000	13,600	81,300	4,890	23,300	407,000	2,160,000	934,000	4,710,000
Total withheld	20,300	80,700	209	3,180	9,280	47,700	8,500	47,800	21,000	120,000
Grand total	80,900	302,000	13,800	84,500	14,200	71,000	XX	XX	955,000	4,830,000

W Withheld to avoid disclosing company proprietary data; included in "Total withheld." XX Not applicable.

1/ Includes a minor amount of limestone-dolomite reported without a distinction between the two.

2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 16
CRUSHED MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Quantity	Value
Coarse aggregate (+1-1/2-inch): Other coarse aggregate	8	137
Coarse aggregate, graded:		
Concrete aggregate, coarse	174	1,390
Bituminous aggregate, coarse	147	979
Bituminous surface-treatment aggregate	95	693
Fine aggregate (-3/8-inch): Screening, undesignated	8	39
Coarse and fine aggregates:		
Graded road base or subbase	439	2,400
Terrazzo and exposed aggregate	42	1,400
Roofing granules	(2/)	2
Other construction materials 3/	616	4,410
Chemical and metallurgical: Lime manufacture	46	1,020
Special:		
Other fillers or extenders	41	1,650
Other specified uses not listed 4/	166	1,090
Unspecified: 5/		
Actual	2,240	15,700
Estimated	2,060	11,700
Total	6,090	42,600

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Includes crusher run (select material or fill), filter stone, other coarse and fine aggregates, other fine aggregate, other graded coarse aggregate, riprap and jetty stone, stone sand (bituminous mix or seal), and unpaved road surfacing.

4/ Includes mine dusting or acid-water treatment, other agricultural uses, and whiting or whiting substitute.

5/ Includes production reported without a breakdown by end use and estimates for respondents.

TABLE 17
CRUSHED GRANITE AND TRAPROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY USE 1/

(Thousand metric tons and thousand dollars)

	Granite		Traprock	
Use	Quantity	Value	Quantity	Value
Coarse aggregate (+1-1/2-inch):				
Macadam	57	300	223	1,420
Riprap and jetty stone	2,790	24,600	2,040	14,400
Filter stone	1,200	9,090	1,310	8,430
Other coarse aggregate	751	5,080	611	4,400
Coarse aggregate, graded:				
Concrete aggregate, coarse	13,600	97,300	7,080	57,900
Bituminous aggregate, coarse	10,900	79,200	7,840	49,300
Bituminous surface-treatment aggregate	3,270	25,800	3,240	26,300
Railroad ballast	5,910	37,500	2,850	19,400
Other graded coarse aggregate	6,360	52,700	909	6,930
Fine aggregate (-3/8-inch):				
Stone sand, concrete	3,840	24,800	1,130	12,400
Stone sand, bituminous mix or seal	6,580	36,800	1,340	8,950
Screening, undesignated	3,880	22,000	2,450	13,200
Other fine aggregate	519	3,740	25	246
Coarse and fine aggregates:				
Graded road base or subbase	20,800	122,000	16,300	85,100
Unpaved road surfacing	1,620	5,920	3,960	16,500
Terrazzo and exposed aggregate	613	4,240	(2/)	(2/)
Crusher run or fill or waste	11,600	68,900	3,960	16,500
Other coarse and fine aggregates	1,570	10,000	4,030	25,400
Roofing granules	942	10,300	1,270	19,900
Other construction materials	207	876	1590 3/	10,300 3/
Other specified uses not listed 4/	601 5/	3,920 5/	(6/)	5

See footnotes at end of table.

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TABLE 17--Continued
CRUSHED GRANITE AND TRAPROCK SOLD OR USED BY PRODUCERS
IN THE UNITED STATES IN 1996, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Granite		Traprock	
	Quantity	Value	Quantity	Value
Unspecified: 7/				
Actual	90,000	595,000	15,200	84,800
Estimated	14,400	72,400	17,200	90,500
Total	202,000	1,310,000	94,600	573,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Included with "Other construction materials."
3/ Includes drain fields and building products.
4/ Includes other agricultural uses.
5/ Includes other fillers or extenders.
6/ Less than 1/2 unit.
7/ Includes production reported without a breakdown by end use and estimates for nonrespondents.

TABLE 18
CRUSHED SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE
UNITED STATES IN 1996, BY USE 1/

(Thousand metric tons and thousand dollars)

Use	Sandstone		Quartzite	
	Quantity	Value	Quantity	Value
Coarse aggregate (+1-1/2-inch):				
Macadam	165	1,040	45	248
Riprap and jetty stone	659	3,920	200	1,160
Filter stone	80	595	53	369
Other coarse aggregate	67	520	W	W
Coarse aggregate, graded:				
Concrete aggregate, coarse	938	5,310	602	3,230
Bituminous aggregate, coarse	1,540	10,900	738	4,330
Bituminous surface-treatment aggregate	408	3,150	290	2,280
Railroad ballast	40	248	46	336
Other graded coarse aggregate	W	W	--	--
Fine aggregate (-3/8-inch):				
Stone sand, concrete	642	3,950	122	965
Stone sand, bituminous mix or seal	552	3,330	201	1,430
Screening, undesignated	412	2,000	396	1,000
Other fine aggregate	336	1,710	--	--
Coarse and fine aggregates:				
Graded road base or subbase	3,870	20,100	814	4,660
Unpaved road surfaces	502	3,040	487	2,660
Terrazzo and exposed aggregate	W	W	W	W
Crusher run or fill or waste	555	2,720	140	803
Other coarse and fine aggregates	156	843	343	3,090
Other construction materials	309	3,130	51	347
Agricultural: Poultry grit and mineral food	(2/)	(2/)	(3/)	(3/)
Chemical and metallurgical:				
Cement manufacture	315	1,260	95	713
Flux stone	9	48	303	3,270
Glass manufacture	--	--	(3/)	(3/)
Special:				
Other fillers or extenders	(2/)	(2/)	--	--
Other specified uses not listed	--	--	99	1,350
Unspecified: 4/				
Actual	10,300	62,500	3,770	21,900
Estimated	5,720	30,200	916	4,740
Total	27,700	162,000	9,720	58,900

W Withheld to avoid disclosing company proprietary data; included with "Other construction materials."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Withheld to avoid disclosing company proprietary data; included in "Total."
3/ Included with "Other specified uses not listed."
4/ Includes production reported without breakdown by end use and estimates for nonrespondents.

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TABLE 19
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE 1/
SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996, BY USE 2/

(Thousand metric tons and thousand dollars)

Use	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Coarse aggregate (+1-1/2-inch):				
Macadam	--	--	W	W
Riprap and jetty stone	W	W	76	745
Filter stone	W	W	102	777
Other coarse aggregate	--	--	115	549
Course aggregate, graded:				
Concrete aggregate, coarse	W	W	581	3,450
Bituminous aggregate, coarse	--	--	925	5,050
Bituminous surface-treatment aggregate	--	--	777	5,200
Railroad ballast	--	--	W	W
Other graded coarse aggregate	W	W	191	1,190
Fine aggregate (-3/8-inch):				
Stone sand, concrete	--	--	W	W
Stone sand, bituminous mix or seal	--	--	213	1,250
Screening, undesignated	54	391	345	1,760
Other fine aggregate	--	--	W	W
Coarse and fine aggregates:				
Graded road base or subbase	398	2,250	2,890	12,500
Unpaved road surfacing	124	201	867	5,200
Terrazzo and exposed aggregate	297	3,140	W	W
Crusher run or fill or waste	W	W	364	1,550
Other coarse and fine aggregates	--	--	145	1,020
Other construction materials	307 3/	1,420 3/	1,010	6,840
Agricultural:				
Poultry grit and mineral food	--	--	(4/)	(4/)
Other agricultural uses	--	--	(4/)	(4/)
Chemical and metallurgical: Cement manufacture	--	--	2,180	5,130
Special: Other fillers or extenders	--	--	(4/)	(4/)
Other miscellaneous uses:				
Light weight aggregate (slate)	--	--	669	7,080
Flour (slate)	--	--	(4/)	(4/)
Other specified uses not listed	68	774	260	1,970
Unspecified: 5/				
Actual	649	4,370	12,800	84,900
Estimated	155	875	8,550	42,100
Total	2,050	13,400	33,000	188,000

W Withheld to avoid disclosing company proprietary data; included with "Other construction materials."
1/ Includes marl, shell, slate, and other stone.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes roofing granules.
4/ Included with "Other specified uses not listed."
5/ Includes production reported without a breakdown by end use and estimates for nonrespondents.

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TABLE 20
RECYCLED ASPHALT AND CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY REGION 1/

	Recycled asphalt						Recycled concrete					
	1995			1996			1995			1996		
Region/Division	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Northeast:												
New England	258	$1,660 r/	$6.44 r/	528	$3,150	$5.97	42 r/	$261 r/	$7.16	63	$346	$5.31
Middle Atlantic	296 r/	2,120 r/	7.15 r/	271	2,360	8.71	193	988	5.12	420	2,280	5.42
Midwest:												
East North Central	89	606	6.81	136	668	4.91	38	135	3.55	23	90	3.91
West North Central	205	919	4.48	119	728	6.12	132	600	4.55	W	W	3.76
South:												
South Atlantic	20	65	3.25	23	124	5.39	W	W	5.86	W	W	5.81
East South Central	W	W	6.67	W	W	4.26	--	--	--	--	--	--
West South Central	576	2,370	5.85	W	W	7.05	W	W	5.56	--	--	--
West:												
Mountain	W	W	2.78 r/	105	547	5.21	W	W	1.00 r/	30	94	3.13
Pacific	84	339	4.04	103	673	6.53	390	1,780	4.55	436	2,460	5.64
Total	1,580	8,280 r/	5.25 r/	1,350	8,630	6.41	912 r/	4,410 r/	4.84 r/	1,170	6,280	5.37

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 21
RECYCLED ASPHALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value
Alabama	--	--	--	W	W	$2.75
Alaska	--	--	--	15	$136	9.07
Arizona	11	$22	$2.00	--	--	--
California	61	198	3.25	62	193	3.11
Colorado	W	W	3.56	W	W	3.67
Connecticut	--	--	--	W	W	5.55
Florida	W	W	4.00	W	W	4.57
Hawaii	--	--	--	W	W	7.40
Idaho	--	--	--	6	18	3.00
Illinois	17	71	4.18	--	--	--
Indiana	14	W	W	W	W	5.33
Iowa	W	W	1.06 r/	2	8	--
Kansas	W	W	3.29	W	W	4.75
Louisiana	9	71	7.89	W	W	16.67
Maine	4	W	W	44	296	6.73
Massachusetts	148	953	6.44	338	1,990	5.90
Minnesota	83	470	5.66	89	586	6.58
Missouri	W	W	6.40	W	W	4.10
Nevada	--	--	--	18	43	2.39
New Hampshire	W	W	7.35 r/	W	W	6.39
New Jersey	172	1,580	9.20	W	W	9.85
New Mexico	W	W	1.00 r/	--	--	--
New York	21	116	5.52	38	211	5.55
Ohio	--	--	--	W	W	6.80
Oregon	20	124	6.20	18	300	16.67
Pennsylvania	103 r/	418 r/	4.06 r/	48	317	6.60
Rhode Island	W	W	6.11	W	W	5.28
South Dakota	32	175	5.47	--	--	--
Tennessee	W	W	6.67	W	W	4.26
Texas	W	W	4.05	W	W	4.26
Utah	--	--	--	W	W	6.56
Vermont	--	--	--	W	W	1.00
Virginia	W	W	1.00	W	W	6.67
Washington	W	W	6.00	W	W	2.33
Wisconsin	59	355	6.02	37	139	3.76
Total	1,580	8,280 r/	5.25 r/	1,350	8,630	6.41

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 22
RECYCLED CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value
Alaska	W	W	$4.40	1	$10	$10.00
California	73	$248	3.40	269	1,530	5.70
Hawaii	W	W	2.17	--	--	--
Idaho	--	--	--	W	W	3.50
Illinois	20	89	4.45	--	--	--
Iowa	W	W	6.41	--	--	--
Maine	31	147	2.14	W	W	2.57
Massachusetts	W	W	10.36 r/	57	328	5.56
Minnesota	W	W	4.37	W	W	3.76
Nevada	--	--	--	6	15	2.50
New Jersey	111	594	5.35	W	W	5.83
New Mexico	W	W	1.00 r/	W	W	4.00
New York	W	W	4.76	W	W	4.49

See footnotes at end of table.

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TABLE 22--Continued
RECYCLED CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995 Quantity (thousand metric tons)	1995 Value (thousands)	1995 Unit value	1996 Quantity (thousand metric tons)	1996 Value (thousands)	1996 Unit value
Oregon	(2/)	1	3.94 r/	W	W	5.41
Pennsylvania	W	W	4.00	3	15	4.00
South Dakota	96	408	4.25	--	--	--
Texas	W	W	5.56	--	--	--
Utah	--	--	--	W	W	2.00
Virginia	W	W	5.86	W	W	5.81
Washington	W	W	4.93	W	W	5.49
Wisconsin	W	W	2.56	23	90	3.91
Total	912 r/	4,410 r/	4.84 r/	1,170	6,280	5.37

r/ Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

TABLE 23
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 1996,
BY REGION AND METHOD OF TRANSPORTATION 1/

(Thousand metric tons)

Region/Division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	9,500	423	(2/)	(2/)	3,260	15,600	28,800
Middle Atlantic	82,600	3,350	2,420	2,330	9,570	52,100	152,000
Midwest:							
East North Central	103,000	6,330	18,500	2,680	11,100	107,000	249,000
West North Central	46,600	3,690	6,550	1,670	11,000	78,100	148,000
South:							
South Atlantic	144,000	19,800	1,860	1,390	12,200	140,000	319,000
East South Central	75,900	2,530	1,620	1,120	8,260	65,900	155,000
West South Central	64,900	19,000	(2/)	4,740	7,610	48,800	145,000
West:							
Mountain	15,000	1,820	(2/)	(2/)	3,590	18,600	39,100
Pacific	29,900	2,280	1,390	6,370	4,690	48,900	93,500
Total	572,000	59,200	32,400	20,300	71,400	575,000	1,330,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

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TABLE 24
NUMBER OF CRUSHED AND BROKEN STONE OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 1996, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No. plants or unspecified		
Alabama	46	4	--	2	--	52
Alaska 1/	2	7	2	3	--	14
Arizona	15	10	1	3	1	30
Arkansas	30	10	6	6	--	52
California	52	23	14	10	1	100
Colorado	10	6	8	3	--	27
Connecticut	17	5	1	--	1	24
Florida	33	29	6	7	3	78
Georgia	73	3	1	1	--	78
Hawaii	10	9	5	3	--	27
Idaho	8	26	4	2	--	40
Illinois	74	53	16	1	--	144
Indiana	72	3	7	3	--	85
Iowa	22	170	2	5	--	199
Kansas	19	83	6	2	--	110
Kentucky	77	8	5	3	--	93
Louisiana	1	1	--	1	11	14
Maine	6	8	1	--	--	15
Maryland	20	7	1	1	--	29
Massachusetts	23	6	3	3	--	35
Michigan	17	9	3	3	--	32
Minnesota	8	31	1	6	--	46
Mississippi	3	1	1	--	--	5
Missouri	96	91	14	10	--	211
Montana	9	4	--	1	--	14
Nebraska	5	3	3	--	--	11
Nevada	10	4	1	--	--	15
New Hampshire	6	3	1	2	--	12
New Jersey	10	1	10	--	--	21
New Mexico	13	15	2	1	--	31
New York	67	13	18	3	--	101
North Carolina	85	8	5	2	--	100
Ohio	82	19	7	2	1	111
Oklahoma	45	8	8	1	--	62
Oregon	26	89	7	15	2	139
Pennsylvania	146	25	20	14	--	205
Rhode Island	7	1	--	--	--	8
South Carolina	30	1	2	1	--	34
South Dakota	8	2	--	--	--	10
Tennessee	101	9	3	3	--	116
Texas	69	46	15	3	--	133
Utah	8	5	4	1	--	18
Vermont	7	4	3	3	--	17
Virginia	92	5	7	--	--	104
Washington	29	53	10	24	--	116
West Virginia	34	7	4	1	--	46
Wisconsin	21	104	5	13	--	143
Wyoming	6	3	1	--	--	10
Total	1,650	1,035	244	168	20	3,117

1/ Data derived, in part, from the Alaska Division of Geological and Geophysical Surveys.

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TABLE 25
U.S. EXPORTS OF CRUSHED STONE IN 1996, BY DESTINATION 1/

(Metric tons)

Destination	Limestone for cement manufacturing	Other	Chalk, crude	Granules, chippings	Total
North America:					
Bahamas, The	190	--	--	--	190
Barbados	--	--	18	14	32
Canada	2,410,000	968	4,040	189,000	2,610,000
Cayman Islands	--	--	--	57	57
Costa Rica	1	--	1	--	2
Jamaica	4,660	--	--	1	4,660
Mexico	1,460	469	124	3,150	5,200
Netherlands Antilles	--	--	--	3,700	3,700
Panama	--	--	33	--	33
Trinidad and Tobago	26,100	--	--	--	26,100
Total	2,450,000	1,440	4,220	196,000	2,650,000
South America:					
Argentina	588	--	--	--	588
Brazil	14,300	--	--	501	14,800
Chile	37	--	--	10	47
Colombia	1,600	1	5	--	1,610
Ecuador	800	37	--	20	857
Peru	200	--	--	--	200
Suriname	21,000	--	--	--	21,000
Venezuela	1,500	--	49	6,560	8,110
Total	40,000	38	53	7,090	47,200
Europe:					
Austria	1,600	--	--	16	1,620
Belgium	54,500	--	4	47	54,500
Denmark	420	--	--	--	420
France	44,100	21	12	5	44,100
Germany	75,200	3,080	154	817	79,300
Greece	700	--	--	--	700
Hungary	3,200	--	--	--	3,200
Iceland	51	--	--	--	51
Ireland	1,460	606	--	--	2,070
Italy	42,100	--	--	140	42,200
Netherlands	2,460	239	--	7,330	10,000
Portugal	--	--	--	3	3
Slovenia	1	--	--	--	1
Spain	680	--	--	--	680
Sweden	8,860	--	--	--	8,860
Switzerland	2,780	--	--	--	2,780
United Kingdom	62,400	325	10	462	63,200
Total	300,000	4,270	181	8,820	314,000
Asia:					
China	8,880	--	--	8,020	16,900
Hong Kong	114	60	--	137	311
India	--	22	--	--	22
Indonesia	6,480	14	--	--	6,490
Japan	173,000	1,680	1	173	175,000
Korea, Republic of	3,520	116	--	34	3,670
Malaysia	1,050	--	--	87	1,140
Singapore	--	209	--	4	213
Taiwan	40,700	36	1	56	40,800
Thailand	700	--	--	--	700
Total	235,000	2,130	2	8,510	246,000

See footnotes at end of table.

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TABLE 25--Continued
U.S. EXPORTS OF CRUSHED STONE IN 1996, BY DESTINATION 1/

(Metric tons)

Destination	Limestone for cement manufacturing	Other	Chalk, crude	Granules, chippings	Total
Oceania:					
Australia	6,330	37	104	--	6,470
Other	--	--	--	190	190
Total	6,330	37	104	190	6,660
Middle East:					
Israel	--	--	1,930	--	1,930
Lebanon	--	--	--	--	--
Qatar	--	--	--	502	502
Saudi Arabia	--	--	--	1,220	1,220
Total	--	--	1,930	1,720	3,650
Africa:					
Egypt	72	--	--	--	72
South Africa	38	--	--	--	38
Total	110	--	--	--	110
Grand total	3,030,000	7,920	6,490	223,000	3,270,000
Total value (thousands)	$20,500	$5,940	$2	$9,900	$36,300

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: U.S. Bureau of the Census.

TABLE 26
U.S. IMPORTS OF CRUSHED STONE AND CALCIUM CARBONATE FINES, BY TYPE 1/

(Thousand metric tons and thousand dollars)

Type	1995 Quantity	1995 C.i.f. value 2/	1996 Quantity	1996 C.i.f. value 2/	1996 Unit price
Crushed stone and chips:					
Limestone 2/	6,400	52,600	7,150	58,300	$8.15
Limestone for flux or cement manufacturing	3,240	24,600	3,480	23,800	6.83
Quartzite	(3/)	390	(3/)	524	1,168
Other	1,200	12,600	664	7,000	10.55
Total	10,800	90,300	11,300	89,600	XX
Calcium carbonate fines: 4/					
Natural chalk	(3/)	7	(3/)	1,260	XX
Calcium carbonates other chalk	7	1,600	3	914	304.67
Total	7	1,610	3	2,170	XX
Grand total	10,900	91,900	11,300	91,800	XX

XX Not applicable.
1/ Data are rounded to three significant digits, except prices; may not add to totals shown.
2/ Excludes limestone for cement manufacturing.
3/ Less than 1/2 unit.
4/ Excludes precipitated calcium carbonates.

Source: U.S. Bureau of the Census.

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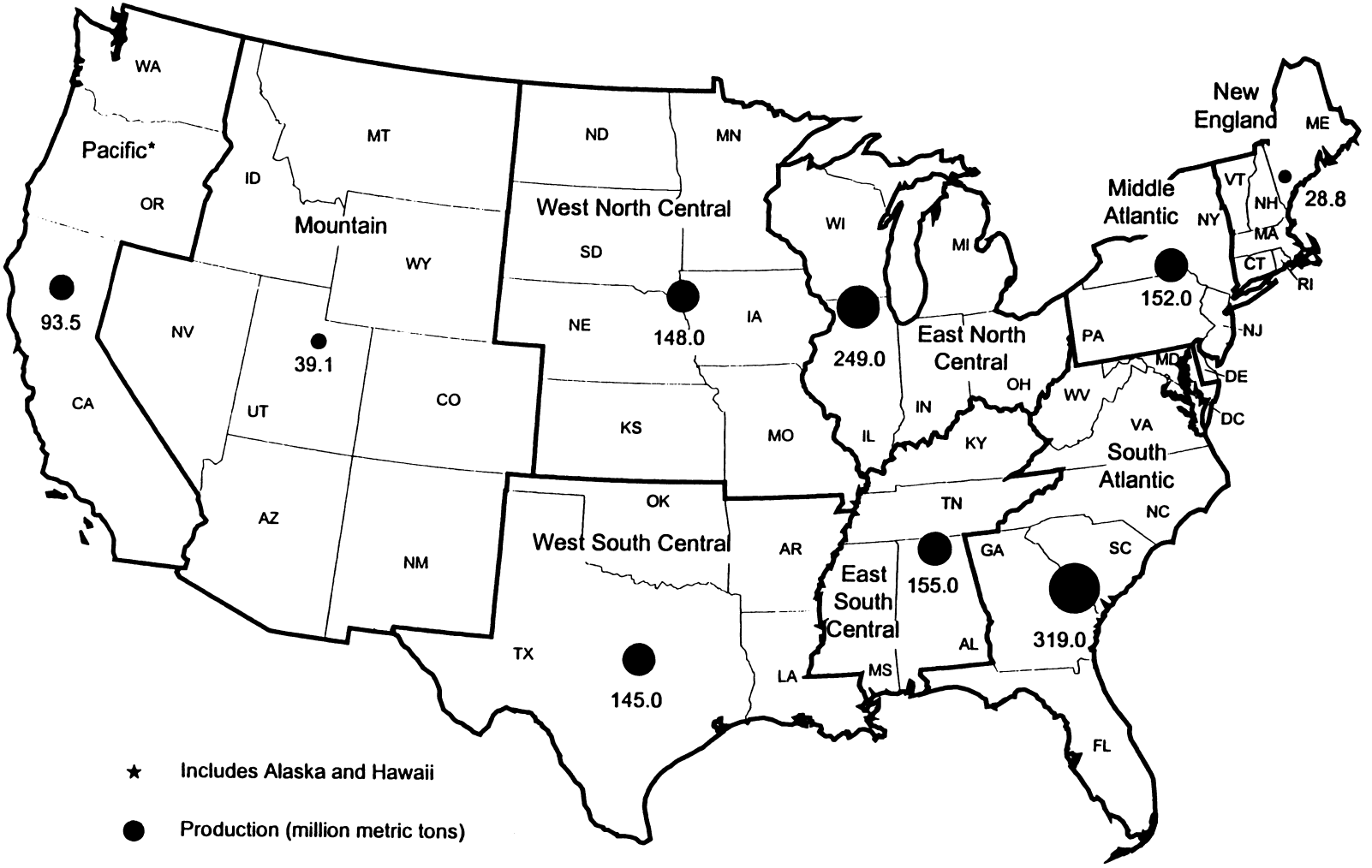
FIGURE 1
PRODUCTION OF CRUSHED STONE IN THE UNITED STATES IN 1996, BY GEOGRAPHIC DIVISION



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DIMENSION STONE

By Jim F. Lemons, Jr.

Dimension stone consists of rough stone and quarried blocks of igneous, sedimentary, and metamorphic rock, including granite, marble, limestone, sandstone, and slate. These stones, because of strength, toughness, hardness, and resistance to environmental damage find application as panels, slabs, and other shapes in building and construction, in monuments, and in curbing.

U.S. stone production data are developed by the U.S. Geological Survey from a voluntary survey of U.S. producers of rough and finished dimension stone. Of the 228 producing dimension stone operations included in the survey for 1996, 174 or 76% responded. These represent 79% of the estimated tonnage for the industry shown in table 1. (*See table 1.*) In addition, 13 former producers were reported to be idle in 1996. In 1996, stone production remained comparable with that of 1995 at 1.15 million metric tons valued at $234 million. Exports of dimension stone decreased slightly in value to $49.5 million. Dimension stone imports for consumption are almost double domestic production at $462 million.

Legislation and Government Programs

U.S. Customs has approved a separate classification of imported monuments and markers from other stone products. This new classification, sought by a coalition of U.S. dimension stone producers, will assist domestic companies in evaluating foreign competition in this product category. Current import duty information is shown for dimension stone products in table 2. *(See table 2.)*

Production

Stone blocks cut or split from a quarry face typically are transported to processing plants, commonly located at the site, for final sizing and finishing operations. Stone finishing may include polishing, edging, and decorating. Recent developments in quarry and processing technology include techniques for utilizing water-jet technology and computer-aided design to produce curved cuts, inlays, medallions, and borders (Dimensional Stone, 1996a).

Of the total dimension stone production in 1996, 44% was granite, 30% was limestone, 13% was sandstone, 2% was marble, 2% was slate, and 9% was miscellaneous stone. Georgia, Indiana, Texas, Vermont, and Wisconsin were the largest dimension-stone-producing States representing 50% of total domestic production. (*See table 3.*)

Leading producing companies (listed alphabetically) were Cold Spring Granite Co., principally in California, Minnesota, South Dakota, and Texas; Eden Stone Co. in Wisconsin; Fletcher Granite Co., Inc. in Massachusetts and New Hampshire; Halquist Stone Co., Inc. in Wisconsin; Indiana Limestone Co., Inc. in Indiana; and Rock of Ages Corp. in Georgia, New Hampshire, and Vermont.

Rock of Ages is now the largest supplier of granite memorials in North America following its merger with two Vermont granite producers, Anderson-Friberg Co. (AFCO) and Lawson Granite Co. Rock of Ages has operations in Canada, Georgia, New Hampshire, and Vermont. More than one-half of its sales are for the granite memorial market (Stone World, 1996c).

Indiana Limestone Co. continues as one of the principal suppliers to the Ronald Reagan Building and International Trade Center in Washington, DC, planned for completion in late 1997. This building will encompass 7,000 cubic meters of limestone, about 42,000 fabricated pieces. Indiana Limestone was also used on the nearby U.S. Commerce Building (Dimensional Stone, 1996b).

Colorado Yule Marble has been chosen for The Women in Military Service Memorial in Washington, DC. This marble was selected to match the exterior marble used in the nearby Lincoln Memorial. The new memorial will be composed of more than 835 square meters of marble in panel thicknesses ranging from 38 to 76 millimeters (Stone World, 1996a).

Granite.—Dimension granite includes all coarse-grained igneous rocks. Production in 1996 remained comparable with 1995 levels at 501,000 tons with a value of $108 million. Granite was produced by 39 companies at 74 quarries in 20 States. Cold Spring Granite, Fletcher Granite, and Rock of Ages were the leading producers (listed alphabetically) and accounted for 56% of U.S. production. Georgia continued to be the leading State, producing 18% of the U.S. total. (*See table 4.*)

Limestone.—Dimension limestone includes bituminous, dolomitic, and siliceous limestones. Production in 1996 decreased 4% compared with 1995 levels, to 350,000 tons, with a 6% decrease in value, to $57.3 million. It was produced by 29 companies at 39 quarries in 10 States. Indiana, the leading State, produced 156,000 tons in 1996, with Wiconsin as the second largest producer and Kansas as the third largest. (*See table 5.*)

Sandstone.—Dimension sandstone includes calcareous- and siliceous-cemented sandstones or conglomerates. Quartzite, which also is included, may be described as any siliceous-cemented sandstone. In 1996, the U.S. total for sandstone increased by 4% from 1995 levels to 151,000 tons valued at $20.1 million. Dimension sandstone was produced by 26 companies at 47 quarries in 15 States. Leading producing States were New York and Pennsylvania. (*See table 6.*)

Consumption

Production during the year was assumed to equal consumption, because nc separate accounting is made of changes in industry stocks. Rough stone represented 50% by tonnage and 36% by value of the dimension stone market. The

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largest uses of rough stone were in building and construction (51%) and monumental (25%). Dressed stone represented 50% by tonnage and 64% by value of the total stone consumed. The largest uses of dressed stone were in ashlars and partially squared pieces at 25%, flagging at 21%, curbing at 19%, and monumental at 8%. (*See table 7.*)

Granite.—Primary uses of the 1996 reported consumption of granite by weight (501,000 tons) were in monumental applications (rough stone 28% and dressed stone 8%), rough blocks for construction 26%, and dressed stone used in curbing 20%. (*See table 8*)

According to a 1996 National Kitchen and Bath Association survey, granite is used 23% of the time for kitchen countertops and 9% of the time in bathroom applications (Stone World, 1996b).

Limestone.—Primary uses of the 1995 reported consumption of limestone by weight (350,000 tons) were in rough blocks for building and construction 41%, and dressed stone for ashlars and partially squared pieces, 18%. (*See table 9.*)

Marble.—Dimension marble includes certain hard limestones, travertines, and any other calcareous stone that can be polished. Marble sold or used in the United States in 1996 is reported to be 27,900 tons valued at $19.9 million. Marble was produced by 7 companies at 13 quarries in 6 States and Puerto Rico. (*See table 10.*)

Sandstone.—Primary uses of the 1996 reported consumption of sandstone by weight (151,000 tons) were in dressed stone for flagging (52%), and dressed stone for ashlars and partially squared pieces (18%). (*See table 11.*)

Slate.—Slate is a fine-grained metamorphic rock derived from shale, siltstone, or claystone. Shale is composed mostly of original clay minerals, and cleavage is parallel to the bedding. Dimension slate sold or used by producers in the United States in 1996 was reported to be 24,700 tons valued at $16.5 million. Slate was produced by 15 companies at 20 quarries in 8 States. Forty-three percent of the slate was used for roofing. (*See table 12.*)

Prices

The average 1996 price for dimension stone remained comparable with 1995 values at $203 per ton. Color and grain structure contribute significantly to price and marketability.

Foreign Trade

Exports.—Exports of dimension stone decreased slightly in value to $49.5 million. The primary export was granite, principally to Italy. There has been some decline in sales to Japan and the Republic of Korea due to increased competition from Chinese producers. (*See table 13.*)

Imports.—Imports for consumption of dimension stone decreased slightly from 1995 values to $462 million, as noted in table 1. A more detailed breakdown by type of stone is shown in tables 13, 14, 15, and 16. Italy remains a principal supplier of granite. Other principal suppliers of granite are Brazil, Canada, and India.

Current Research and Technology

The development of techniques to use thin sandwich panels of stone attached to various backings with the use of adhesives has opened applications of stone usage in luxury cruise liners as walls and floors and in residential markets as dividing panels, countertops, and doors. (Napoli and Ragore, 1996).

The use of high-precision water-jet technology makes it possible to create very complicated designs with near zero tolerance levels on an industrial scale. This technology can cut angles of a fraction of a degree, work with inclinations of up to 45°, cut groves less than 1.5 millimeters and cut round shapes and curves (Dimensional Stone, 1996a).

Outlook

Demand is expected to grow for dimension stone during the next 5 to 10 years because of applications in residential markets, improved technology and variety, and the increased costs of alternate construction materials. In office building construction, growth is expected in the renovation markets. Current high commercial vacancy rates has increased competition in attracting and keeping tenants, causing some owners to upgrade appearance with stone (Reis, 1996).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT U.S. DIMENSION STONE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
Sold or used by producers:					
Quantity 2/	1,140	1,280	1,190	1,160	1,150
Value 2/	$198,000	$226,000	$218,000	$233,000	$234,000
Exports (value)	$54,900	$52,700	$53,000	$51,800	$49,500
Imports for consumption (value)	$404,000	$398,000	$440,000	$478,000	$462,000

1/ Data are rounded to three significant digits.
2/ Includes Puerto Rico.

TABLE 2
U.S. IMPORT DUTIES ON DIMENSION STONE

Tariff item	HTS. No.	Most favored nation (MFN) Jan. 1, 1997	Non-MFN Jan. 1, 1997
Slate: Rough blocks or slabs	2514.00.0000	2.2% ad valorem	25% ad valorem.
Rough blocks or slabs of marble, travertine, and other calcareous monumental or building stone	2515.00.0000		
Marble and travertine:			
Crude or roughly trimmed	2515.11.0000	$2.08 per cubic meter	$22.95 per cubic meter.
Marble, merely cut	2515.12.0010	1.3% ad valorem	13% ad valorem.
Travertine, merely cut	2515.12.0020	4.8% ad valorem	50% ad valorem.
Other calcareous stone alabaster	2515.20.0000	4.8% ad valorem	50% ad valorem.
Rough blocks or slabs of granite, porphyry, basalt, sandstone, and other monumental or building stone	2516.00.0000		
Granite:			
Crude or roughly trimmed	2516.11.0000	Free	$8.83 per cubic meter.
Merely cut	2516.12.0000	3.6% ad valorem	60% ad valorem.
Sandstone:			
Crude or roughly trimmed	2516.21.0000	Free	$5.30 per cubic meter.
Merely cut	2516.22.0000	4.8% ad valorem	50% ad valorem.
Other monumental or building stone	2516.90.0000	4.8% ad valorem	50% ad valorem.
Setts, curbstones, and flagstones	6801.00.0000	3.6% ad valorem	60% ad valorem.
Worked monumental or building stone	6802.00.0000		
Tiles and cubes under 7 centimeters square, granules	6802.10.0000	6.1% ad valorem	40% ad valorem.
Other stone and articles with a flat or even surface:			
Marble, travertine, and alabaster:	6802.21.0000		
Travertine	6802.21.1000	5.3% ad valorem	50% ad valorem.
Other	6802.21.5000	2% ad valorem	13% ad valorem.
Other calcareous stone	6802.22.0000	5.6% ad valorem	50% ad valorem.
Granite	6802.23.0000	4% ad valorem	60% ad valorem.
Other stone	6802.29.0000	6.9% ad valorem	30% ad valorem.
Other:			
Marble, travertine, and alabaster:	6802.91.0000		
Marble:			
Slabs	6802.91.0500	2.7% ad valorem	15% ad valorem.
Other	6802.91.1500	5.6% ad valorem	50% ad valorem.
Travertine:			
Articles of subheading 6802.21.1000 that have been dressed or polished, but not further worked	6802.91.2000	5.3% ad valorem	50% ad valorem.
Other	6802.91.2500	4.7% ad valorem	40% ad valorem.
Alabaster	6802.91.3000	5.1% ad valorem	50% ad valorem.
Other calcareous stone	6802.92.0000	5.6% ad valorem	50% ad valorem.
Granite	6802.93.0000	4% ad valorem	60% ad valorem.
Other stone	6802.99.0000	6.5% ad valorem	40% ad valorem.
Worked slate and articles:	6803.00.0000		
Roofing slate	6803.00.0010	5.3% ad valorem	25% ad valorem.
Other	6803.00.0050	2.2% ad valorem	25% ad valorem.

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TABLE 3
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1/ BY STATE 2/

State	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
California	27,300	$6,660	28,600	$7,020
Colorado	17,800	2,640	23,900	3,330
Georgia 3/	125,000	13,800	89,600	10,300
Indiana 3/	172,000	31,400	156,000	24,500
Kansas 3/	19,800	1,810	21,400	2,100
Maryland	20,700	2,260	19,800	2,210
Massachusetts	77,600	14,600	79,600	15,000
Minnesota	--	--	25,400	10,700
New Hampshire	23,000	6,290	29,000	6,500
New York	33,900	8,440	34,400	8,120
North Carolina	41,100	15,400	37,300	14,300
Ohio	--	--	19,800	2,060
Oklahoma	9,170	2,350	9,710	2,220
Pennsylvania	57,600	12,300	54,300	11,800
Texas	--	--	86,600	21,100
Vermont	100,000	28,700	99,600	27,900
Wisconsin	128,000	14,500	143,000	16,600
Other 4/	308,000	72,000	196,000	48,000
Total	1,160,000	233,000	1,150,000	234,000

1/ Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Totals only include Georgia granite, Indiana limestone, and Kansas limestone; other stone included with "Other."
4/ Includes data for Alabama, Arizona, Arkansas, Connecticut, Idaho, Iowa (1995), Maine, Michigan, Minnesota (1995), Missouri, Montana, New Mexico, South Carolina, South Dakota (1996), Tennessee, Texas (1995), Utah (1996), Virginia (1996), Washington, and West Virginia.

TABLE 4
DIMENSION GRANITE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE 1/

State	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Georgia	125,000	$13,800	89,600	$10,300
Massachusetts	77,600	14,600	79,600	15,000
New Hampshire	23,000	6,290	29,000	6,500
North Carolina	41,100	15,400	34,700	13,800
Oklahoma	6,960	2,180	5,760	1,990
Pennsylvania	8,050	2,670	6,140	2,040
Other 2/	214,000	49,200	256,000	58,500
Total	495,000	104,000	501,000	108,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes California, Colorado, Connecticut, Maine, Minnesota, Missouri, New Mexico, New York, South Carolina, South Dakota, Texas, Vermont, Virginia, and Wisconsin.

TABLE 5
DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE
UNITED STATES, BY STATE 1/

State	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Indiana	172,000	$31,400	156,000	$24,500
Kansas	19,800	1,810	21,400	2,100
Oklahoma	2,220	176	2,220	176
Wisconsin	120,000	11,600	133,000	13,500
Other 2/	48,800	16,200	38,100	17,100
Total	363,000	61,200	350,000	57,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes Alabama, Arkansas, California, Iowa (1995), Minnesota, New Mexico (1995), Ohio, Pennsylvania (1996), Texas, Utah (1995), and Vermont (1996).

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TABLE 6
DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/

State	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
New York	26,100	$6,300	28,200	$6,730
Pennsylvania	22,900	3,320	23,700	3,390
Other 2/	95,800	7,540	99,000	9,950
Total	145,000	17,200	151,000	20,100

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes Alabama, Arizona, Arkansas, California, Colorado, Kansas, Michigan, North Carolina, Ohio, Oklahoma, Utah, West Virginia, and Wisconsin.

TABLE 7
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1/ BY USE 2/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Rough stone:				
Rough blocks for building and construction	287,000	$31,200	295,000	$36,900
Irregular-shaped stone	99,300	9,360	74,500	8,300
Monumental	141,000	20,600	143,000	23,000
Other 3/	66,300	13,500	68,100	17,200
Dressed stone:				
Ashlars and partially squared pieces	135,000	26,200	142,000	25,700
Slabs and blocks for building and construction	30,800	16,000	29,400	10,700
Monumental	50,300	27,100	44,400	28,100
Curbing	126,000	26,300	106,000	22,600
Flagging	99,300	9,290	121,000	11,900
Flagging (slate)	5,460	713	4,340	747
Roofing slate	14,300	11,200	10,600	10,200
Structural and sanitary	5,480	4,550	1,430	2,080
Flooring slate	4,530	2,030	3,610	1,950
Other 4/	99,800	36,300	107,000	34,900
Total	1,160,000	233,000	1,150,000	234,000

1/ Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes flagging (1996), exports, and uses not specified.
4/ Includes panels and veneer (1996), tile (1996), exports, and uses not specified.

TABLE 8
DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Rough stone:				
Rough blocks for building and construction	100000	$13,900	128000	$18,400
Irregular-shaped stone 2/	43900	7720	1050	355
Monumental	136000	19400	140000	20400
Other 3/	--	--	23500	7650
Dressed stone:				
Ashlars and partially squared pieces	32800	9180	35600	9750
Slabs and blocks for building and construction	830	664	2470	634
Monumental	45600	18100	39700	19000
Curbing	122000	25800	102000	22100
Other 4/	13,600	9,270	29,100	9,810
Total	495,000	104,000	501,000	108,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes exports (1995), and uses not specified (1995).
3/ Includes exports and uses not specified.
4/ Includes panels and veneer (1996), tile (1996), flagging (1995), paving blocks (1995), and uses not specified.

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TABLE 9
DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Rough stone:				
Rough blocks for building and construction	148,000	$13,200	143,000	$15,100
Irregular-shaped stone 2/	43,700	5,440	27,300	2,090
Other 3/	--	--	23,100	8,910
Dressed stone:				
Ashlars and partially squared pieces	62,300	12,300	64,700	10,200
Slabs and blocks for building and construction	20,700	8,280	19,300	3,370
Flagging	25,100	2,210	24,600	2,080
Other 4/	63,300	19,800	48,200	15,600
Total	363,000	61,200	350,000	57,300

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes exports (1995) and uses not specified (1995).
3/ Includes exports and uses not specified.
4/ Includes panels and veneer (1996), tile (1996), monumental (1995), curbing, and uses not specified.

TABLE 10
DIMENSION MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1/ BY USE 2/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Rough stone:				
Rough blocks for building and construction	W	W	W	W
Irregular-shaped stone	--	--	W	W
Monumental	--	--	W	W
Other 3/	18,500	$4,430	13,200	$2,360
Dressed stone:				
Ashlars and partially squared pieces	3,110	504	3,110	517
Slabs and blocks for building and construction	5,430	6,500	2,490	5,750
Other 4/	12,500	9,700	9,120	11,300
Total	39,600	21,100	27,900	19,900

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Includes Puerto Rico.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes rubble (1995), exports (1995), and uses not specified.
4/ Includes panels and veneer (1996), tile (1996), monumental, curbing (1996), flagging, and uses not specified.

TABLE 11
DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Rough stone:				
Rough blocks for building and construction	14,200	$779	W	W
Irregular-shaped stone 2/	33,700	3,330	19,800	$3,040
Other 3/	--	--	1,460	247
Dressed stone:				
Ashlars and partially squared pieces	24,300	2,720	27,700	2,820
Slabs and blocks for building and construction	1,950	420	3,350	799
Flagging	64,200	6,060	79,200	8,330
Other 4/	6,400	3,820	19,500	4,840
Total	145,000	17,200	151,000	20,100

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes rubble (1995).
3/ Includes uses not specified.
4/ Includes panels and veneer (1996), monumental (1995), curbing, exports (1996), and uses not specified.

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TABLE 12
DIMENSION SLATE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/

Use	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Flagging	5,620	$733	4,340	$747
Roofing	15,300	12,100	10,600	10,200
Structural and sanitary purposes	5,480	4,550	1,430	2,080
Flooring	4,580	2,030	3,610	1,950
Other 2/	4,680	2,230	4,740	1,490
Total	35,600	21,600	24,700	16,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes billiard tabletops, blackboards, school slates (1995), and uses not specified.

TABLE 13
U.S. EXPORTS OF DIMENSION STONE, BY TYPE 1/

(Thousand metric tons and thousand dollars)

Type	1995 Quantity	1995 Value	1996 Quantity	1996 Value	Major destination 2/ in 1996, (percent)
Marble, travertine, alabaster worked	27	3,770	24	3,390	Canada, 22%.
Marble, travertine - crude or roughly trimmed	3	879	2	782	Japan, 52%.
Marble, travertine - merely cut, by sawing or otherwise	19	1,620	2	1,520	United Kingdom, 31%.
Granite, crude or roughly trimmed	124	24,300	114	28,500	Italy, 43%.
Granite, merely cut by sawing or otherwise	34	10,300	23	3,840	Taiwan, 34%.
Sandstone, crude or roughly trimmed	2	398	3	437	Canada, 73%.
Sandstone, merely cut, by sawing or otherwise	4	931	5	879	Canada, 96%.
Slate, worked and articles of slate	NA	5,520	NA	5,710	Belize, 37%.
Slate, whether or not roughly trimmed or merely cut	NA	443	NA	280	Canada, 66%.
Other calcareous monumental or building stone; alabaster	4	1,570	8	1,370	Japan, 31%.
Other monumental or building stone	10	2,070	16	2,810	Canada, 42%.
Total	XX	51,800	XX	49,500	

NA Not available. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ By value.

Source : Bureau of the Census.

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TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF DIMENSION GRANITE, BY COUNTRY 1/

(Thousand dollars)

Country	Rough granite 2/	Dressed granite articles	Dressed worked granite: Not cut to size	Cut to size: Max 1.5 centimeters	Cut to size: 1.5-7.5 centimeters 3/	Cut to size: Monumental Min 7.5 centimeters 3/	Cut to size: Building Min 7.5 centimeters 3/	Other	Total worked	Total dressed
1995:										
Argentina	29	142	82	59	119	--	--	172	432	574
Brazil	316	1,870	5,460	754	6,760	18	476	3,760	17,200	19,100
Canada	3,020	1,200	3,220	474	2,360	3,420	1,700	5,800	17,000	18,200
China	383	955	645	939	347	118	388	1,540	3,980	4,940
Finland	37	2	--	--	9	4	31	71	115	117
India	1,580	3,120	2,400	3,180	7,940	3,050	2,610	2,740	21,900	25,000
Italy	1,050	5,410	9,460	2,660	14,400	107	1,830	21,600	50,100	55,500
Japan	--	37	9	--	--	--	9	185	203	240
Mexico	9	30	63	72	547	--	2	6	690	720
Norway	190	6	--	--	74	15	5	--	94	100
Portugal	--	53	19	--	20	--	--	29	68	121
Saudi Arabia	26	176	334	19	220	--	16	57	646	822
South Africa	992	92	26	188	61	--	189	482	946	1,040
Spain	7	379	1,460	955	2,140	33	206	1,330	6,120	6,500
Other	557	627	467	701	413	66	302	758	2,710	3,330
Total	8,200	13,900	23,600	9,520	35,400	6,830	7,770	38,500	122,000	136,000
1996:										
Argentina	33	286	83	25	141	22	28	97	396	682
Brazil	327	1,820	4,410	1,310	6,400	1,180	1,140	4,860	19,300	21,100
Canada	4,220	938	1,330	1,040	2,250	6,120	3,830	8,580	23,100	24,100
China	243	404	461	794	737	292	637	1,430	4,350	4,760
Finland	6	--	--	--	--	--	67	169	236	236
India	1,510	3,260	1,620	2,370	6,410	3,090	1,510	4,220	19,200	22,500
Italy	1,780	6,150	13,600	4,890	16,200	2,540	5,100	19,300	61,600	67,700
Japan	4	136	--	--	14	13	4	9	40	176
Mexico	173	6	26	116	1,280	10	312	39	1,780	1,790
Norway	14	--	--	--	--	--	--	--	--	--
Portugal	3	104	25	--	12	--	58	8	103	207
Saudi Arabia	19	40	187	21	117	58	4	41	428	468
South Africa	721	183	--	--	16	23	20	107	166	349
Spain	65	576	1,250	492	3,610	1,200	804	981	8,320	8,900
Other	790	225	89	252	350	159	565	773	2,190	2,410
Total	9,910	14,100	23,000	11,300	37,500	14,700	14,100	40,600	141,000	155,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes crude or roughly trimmed, and merely cut by sawing or otherwise.
3/ 1995 data based on 10 centimeters instead of 7.5 centimeters.

Sources: Bureau of the Census.

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TABLE 15
U.S. IMPORTS FOR CONSUMPTION OF MAJOR CATEGORIES OF DIMENSION MARBLE AND OTHER CALCAREOUS STONE, BY COUNTRY 1/

Country	Dressed marble slabs		Dressed marble - other		Dressed marble and other calcareous stone 2/		Rough marble 3/	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
China	1,350	$932	2,880	$2,720	1,710	$1,520	358	$158
France	119	138	104	154	11,200	15,000	35	38
Greece	4,180	4,970	3,520	3,750	3,940	4,170	2	3
India	1,170	828	1,230	1,310	469	389	83	115
Italy	23,700	22,700	37,000	35,200	31,800	29,500	1,110	1,000
Mexico	766	769	2,680	2,120	6,300	5,400	74	67
Portugal	1,180	1,100	1,280	1,120	6,470	4,670	--	--
Spain	3,730	3,480	7,740	7,800	28,700	28,000	268	135
Other	11,100	8,600	8,270	12,700	44,900	8,980	349	466
Total	47,300	43,500	64,700	66,800	136,000	97,600	2,280	1,990
1996:								
China	847	703	3,690	3,140	7,530	2,330	51	60
France	74	65	38	77	29,900	12,900	275	95
Greece	4,380	5,270	4,350	4,670	4,050	3,870	281	268
India	598	588	710	837	1,310	499	12	13
Italy	24,200	25,200	38,800	37,200	42,000	35,700	2,920	1,640
Mexico	353	483	4,870	4,670	5,580	5,230	489	309
Portugal	1,280	1,180	1,330	1,270	12,800	9,450	92	12
Spain	2,880	2,490	9,360	9,680	30,100	27,300	287	218
Other	9,180	7,470	10,900	13,600	17,200	12,900	438	597
Total	43,700	43,400	74,100	75,200	150,000	110,000	4,850	3,210

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ HTS No. 6802.92.0000
3/ Merely cut by sawing or otherwise.

Source: Bureau of the Census as modified by the U.S. Geological Survey.

TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF DIMENSION STONE, BY TYPE 1/

Type		1995		1996		Major source 2/ for 1996, (percent)
		Quantity	Value (thousands)	Quantity	Value (thousands)	
Calcareous stone-other 3/	metric tons	48,700	$5,920	32,200	$7,030	Spain, 27%.
Marble, travertine, alabaster, and other	do.	6,150	4,200	7,030	5,180	Italy, 57%.
Sandstone, merely cut, by sawing or otherwise	do.	261	268	593	182	India, 81%.
Slate, roofing	million square feet	8	3,730	7	3,560	China, 45%.
Slate, whether or not roughly trimmed or merely cut	do.	2,280	832	1,880	755	Italy, 33%.
Slate, worked and articles of slate, and other	do.	NA	25,900	NA	27,700	Italy, 39%.
Stone, worked monumental or building stone-other	metric tons	64,300	60,400	NA	NA	Italy, 0%.
Travertine, monumental or building stone and articles thereof	do.	6,320	4,180	5,100	3,430	Italy, 74%.
Travertine, worked monumental or building stone	do.	17,100	13,000	49,900	15,600	Italy, 77%.
Other monumental or building stone	do.	20,700	4,650	NA	NA	Italy, 0%.
Other stone-monumental or building stone-articles thereof	do.	2,760	1,300	4,890	1,410	Mexico, 41%.

NA Not available.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ By value.
3/ HTS No. 6802.22.0000.

Source: Bureau of the Census.

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STRONTIUM

By Joyce A. Ober

Prompted by the expected demand for additional strontium carbonate for the television glass industry, new strontium carbonate production facilities were completed in the early 1990's and celestite production increased, but not as dramatically as the earlier increases in strontium carbonate capacity. Significant increases in world production of celestite indicate that the capacity utilization of strontium carbonate facilities is beginning to expand in response to the additional demand for strontium carbonate required to supply newly completed television glass plants. Chemical Products Corp. (CPC) of Cartersville, GA, is the only U.S. producer of strontium compounds from celestite. CPC produces strontium carbonate from imported Mexican ore; no celestite mines are active in the United States.

Strontium occurs commonly in nature, averaging 0.034% of all igneous rock; however, only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities currently attractive. Strontianite would be the more useful of the two common minerals because strontium is used most commonly in the carbonate form, but few deposits have been discovered that are suitable for development. Only one strontianite mine is believed to operate in the world.

Legislation and Government Programs

Government stockpiling of celestite began in 1942 to provide a secure supply of celestite for the production of strontium compounds required for defense applications during World War II. Celestite purchase specifications issued in 1960 for the U.S. National Defense Stockpile established quality requirements at greater than 95% strontium sulfate content with less than 1.5% calcium sulfate and less than 2% barium sulfate.

In 1963, the celestite stockpile was determined to be unnecessary, and the General Services Administration began selling stockpile material. All the stockpile-grade celestite was sold by 1973, with the remaining material grading less than 91% strontium sulfate and more than 4% calcium sulfate and some with more than 10% barium sulfate.

The stockpile currently contains approximately 12,000 tons of celestite, all of which have been authorized for disposal. The low quality of the material remaining in the stockpile makes it undesirable as a raw material for strontium carbonate production. Reports issued by the Defense Logistics Agency, Defense National Stockpile Center—the agency now responsible for managing stockpile sales—list the celestite as valueless.

Production

Although there have been no active celestite mines in the United States since 1959, celestite deposits have been identified nationwide. During World War II, domestic mining of celestite resources was conducted in California and Texas. U.S. celestite mines had at that time been inactive since World War I, and strontium minerals were imported to satisfy domestic demand.

The sole U.S. strontium carbonate producer voluntarily provided domestic production and sales data to the U.S. Geological Survey (USGS). Production and stock data, however, were withheld from publication to avoid disclosing company proprietary data. *(See table 1.)* CPC is the only domestic company that produces strontium carbonate from celestite; the company also produces strontium nitrate. All the celestite CPC used in 1995 was imported from Mexico. CPC owns and operates a second strontium carbonate plant in Reynosa, Tamaulipas, Mexico. The company uses the black ash method of strontium carbonate production at both of its facilities.

The black ash method and the soda ash method are the two most common recovery techniques. The black ash method, known alternatively as the calcining method, produces chemical-grade strontium carbonate, which contains at least 98% strontium carbonate. The soda ash or direct conversion method produces technical-grade strontium carbonate, containing at least 97% strontium carbonate. The first step in the black ash process involves mixing the crushed and screened celestite with powdered coal. The mixture is then heated to about 1,100° C, expelling oxygen in the form of carbon dioxide from the insoluble strontium sulfate to form water-soluble strontium sulfide. Strontium sulfide is dissolved in water and the resulting solution filtered. Carbon dioxide is then passed through the solution or soda ash is added, forming and precipitating strontium carbonate from solution. The precipitated strontium carbonate is then filtered, dried, ground, and packaged. The byproduct sulfur from the process is recovered as elemental sulfur or as other byproduct sulfur compounds.

In the soda ash method, ground celestite is washed and most of the water removed. The thickened mixture is combined with soda ash and treated with steam for 1 to 3 hours. During this time, celestite and soda ash react to form strontium carbonate and sodium sulfate. Sodium sulfate is water soluble, making it possible to separate the insoluble strontium carbonate by centrifuging. The black ash method is the preferred means of strontium carbonate production due to the higher grade product,

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and most new production facilities employ black ash technology.

Several U.S. companies produced strontium metal and compounds from strontium carbonate. Calstron Corp. of Memphis, TN, a subsidiary of KB Alloys Inc. of Reading, PA, produced strontium metal. Mallinkrodt Inc. of St. Louis, MO, produced strontium chloride, and Mineral Pigments Corp. of Beltsville, MD, produced strontium chromate. A few other companies produced downstream strontium compounds, but on a limited scale.

Consumption

The USGS estimated the distribution of strontium compounds by end use. Of the 11 operations to which a survey request was sent, all responded. The information collected from this survey and the information provided by the U.S. Bureau of the Census on strontium trade were the basis for the end-use estimates shown in table 2.

In 1996, more than 80% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and ceramic ferrite magnets, and in smaller amounts in other ceramic and glass applications. Over the past 20 years, production of faceplate glass for color television picture tubes has become the major consumer of strontium.

All color televisions and other devices containing color cathode-ray tubes sold in the United States are required by law to contain strontium in the faceplate glass of the picture tube to block X-ray emissions. Major manufacturers of television picture tube glass incorporate about 8%, by weight, strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, it is converted to strontium oxide. In addition to blocking X-rays, the strontium improves the appearance of the glass, increasing the brilliance and improving the quality of the picture.

Permanent ceramic magnets are another large end use for strontium compounds, in the form of strontium ferrite. These magnets are used extensively in small direct current motors used in automobile windshield wipers, loudspeakers, other electronic equipment, toys, and magnetically attached decorative items. Strontium ferrite magnets have high coercive force, high thermal and electrical resistivity, and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, do not react with most chemical solvents, resist demagnetization, and are low density.

One of the most consistent and continuing applications for strontium has been in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material has been found to be better in this application.

The strontium compound used most frequently in pyrotechnic devices was strontium nitrate. Strontium carbonate, strontium oxalate, strontium sulfate, and strontium chlorate can be used in pyrotechnic applications, but strontium nitrate is used in significantly larger quantities than any of these. Pyrotechnic devices are used in military and nonmilitary applications. Military pyrotechnic applications that contained strontium included tracer ammunition, military flares, and marine distress signals. Nonmilitary applications include warning devices and fireworks.

Strontium is used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate in sulfuric acid to the electrolyte reduces the lead content of the electrolyte and of the zinc that is deposited on the cathode.

Strontium chromate is an additive to corrosion-resistant paint. It is an effective coating for aluminum, most notably on aircraft fuselages and ships. These paints are used to some degree on aluminum packaging to prevent package corrosion.

Strontium metal is a very limited part of total strontium consumption. Small amounts of strontium are added to molten aluminum to improve the castability of the metal, making it more suitable for casting items that have been traditionally made from steel. The addition of strontium to the melt improves the machinability of the casting. The use of cast aluminum parts is currently gaining popularity in the automotive industry because the weight reduction of the automobile from using cast aluminum parts instead of steel improves gas mileage.

Other end uses consume only small amounts of strontium and strontium compounds. As mentioned previously, the presence of strontium in glass applications improves the brilliance of the glass. It also improves the quality of certain ceramic glazes as well as eliminates the toxicity that may be present in glazes containing lead or barium. Strontium titanate is sometimes used as substrate material for semiconductors and in some optical and piezoelectric applications. Strontium chloride is used in toothpaste for temperature-sensitive teeth. For this application, impurities must be strictly controlled, with limits for some of them in the parts per million range. Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals was used in analytical chemistry laboratories. *(See table 2.)*

Prices

The average customs value for celestite imported from Mexico was about $67 per ton, 6% lower than the average value in 1995. The average unit customs value of imported strontium carbonate was $0.61 per kilogram, the same as that in 1995. The corresponding value for strontium nitrate was $1.98 per kilogram, an increase of more than 100%.

Foreign Trade

According to reports from the U.S. Bureau of the Census, exports of strontium compounds decreased about 10% from the levels reported in 1995. Imports of celestite–all from Mexico–were 26,400 tons, a decrease of about 9% from the 1995 level. Although celestite import figures vary significantly from year to year, this appears to be attributable to a 2-year cycle of celestite imports; however, during the past 2 years, trade data indicate a developing trend toward lower celestite imports. Over the past 5 years, annual celestite imports averaged about 33,000 tons (14,000 tons contained strontium)

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT STRONTIUM STATISTICS 1/

(Metric tons of contained strontium unless otherwise noted 2/)

	1992	1993	1994	1995	1996
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: 3/					
Strontium minerals	19,700	11,600	16,000	12,700	11,600
Strontium compounds	13,000	15,300	20,000	20,800	20,500
Exports (compounds) 3/	650	260	1,120	1,160	712
Shipments from Government stockpile excesses	--	--	--	--	--
Price, average value of mineral imports at port of exportation, dollars per ton	$68	$73	$68	$71	$67
World production 4/ (celestite)	195,000 r/	201,000 r/	233,000 r/	291,000 r/	297,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ The strontium content of celestite is 43.88%, which was used to convert units of celestite.

3/ Source: Bureau of the Census.

4/ Excludes China and the former U.S.S.R.

TABLE 2
U.S. ESTIMATED DISTRIBUTION OF PRIMARY
STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	1995	1996
Electrolytic production of zinc	2	2
Ferrite ceramic magnets	8	9
Pigments and fillers	4	3
Pyrotechnics and signals	7	9
Television picture tubes	75	73
Other	4	4
Total	100	100

TABLE 3
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1995		1996	
	Quantity (mertic tons)	Value 2/ (thousands)	Quantity (mertic tons)	Value 2/ (thousands)
Strontium carbonate precipitated:				
Canada	338	$313	339	$304
Japan	51	53	(3/)	6
Malaysia	1,090	362	--	--
Mexico	--	--	24	23
Singapore	--	--	12	11
Other	1	13	6	25
Total	1,480	740	381	368
Strontium oxide, hydroxide, and peroxide:				
Australia	--	--	255	140
Belgium	56	52	19	17
Canada	22	12	21	12
Germany	76	42	84	46
Israel	--	--	26	15
Japan	50	42	165	149
Norway	--	--	25	14
Taiwan	--	--	88	49
Turkey	25	14	--	--
United Kingdom	--	--	491	270
Venezuela	11	14	--	--
Other	9	13	--	--
Total	249	189	1,170	711

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Customs value.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1995		1996	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Strontium carbonate:				
China	147	$75	377	$215
Germany	4,540	2,930	3,360	2,230
Mexico	30,200	18,100	30,500	18,400
Other	18	74	10	104
Total	34,900	21,200	34,300	20,900
Strontium nitrate:				
China	--	--	20	96
France	--	--	5	35
Mexico	160	137	111	138
United Kingdom	11	19	--	--
Other	1	6	--	--
Total	171	162	136	269

1/ Data rounded to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
CELESTITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Algeria e/	5,400	5,400	5,400	5,400	5,400
Argentina	1,200 e/	4,806 r/	8,484 r/	9,325 r/	9,000
Iran e/ 4/	13,138 5/	20,000	20,000	20,000	20,000
Mexico	61,097	71,900	70,000 e/	138,342 r/	143,892 5/
Pakistan	1,448	1,684	2,320 r/	1,625 r/	2,500
Spain	72,295 r/	52,968 r/	102,046 r/	90,972 r/	91,000
Turkey	37,940	43,700	25,000 r/	25,000 e/	25,000
United Kingdom e/	2,000	1,000	--	--	--
Total	195,000 r/	201,000 r/	233,000 r/	291,000 r/	297,000

e/ Estimated. r/ Revised.
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 15, 1997.
3/ In addition to the countries listed, China and the former U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.
4/ Data are for year beginning Mar. 21 of that stated.
5/ Reported figure.

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SULFUR

By Joyce A. Ober

Through its major derivative sulfuric acid, sulfur ranks as one of the more important elements used as an industrial raw material. It is of prime importance to every sector of the world's industrial and fertilizer complexes. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indexes of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other chemical; nearly 48 million metric tons, equivalent to about 16 million tons of elemental sulfur, were produced, slightly more than that of 1995 (Chemical and Engineering News, 1997).

Domestic production of sulfur remained level, although shipments, consumption, U.S. trade, and prices decreased. The United States maintained its position as the leading producer and consumer of sulfur and sulfuric acid. The quantity of sulfur recovered during the refining of petroleum and the processing of natural gas continued the upward trend established in 1939, the second year the U.S. Bureau of Mines (USBM) published data on the production of this type of sulfur in its Minerals Yearbook. This data series has continued at the U.S. Geological Survey (USGS) since the minerals information activities of the USBM were transferred in 1996. The production of sulfur by using the Frasch process was about 8% lower than that of 1995, which was due to intentional cutbacks to improve the balance between supply and demand. Frasch production data were estimated on the basis of company reports published by the single company that continues to produce Frasch sulfur. Total production of sulfur from all sources was level, shipments declined, and stocks increased.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, essentially mandated by laws concerning sulfur dioxide emissions, supplied a significant quantity of sulfuric acid to the domestic merchant (commercial) acid market. Production increased slightly.

World sulfur production was slightly lower than that of 1995. Frasch production was significantly lower because of production decreases in Poland and the United States. Elemental sulfur production from recovered sources, primarily during the processing of natural gas and petroleum products, increased slightly. More than three-quarters of the world's elemental sulfur production came from recovered sources; the quantity of sulfur supplied from these sources was dependent on the world demand for fuels and petroleum products, not on the demand for sulfur.

World sulfur consumption remained about the same with no change in the way it was divided among fertilizer production and in a myriad of industrial uses. World trade of elemental sulfur decreased about 3% from the levels recorded in 1995. U.S. sulfur inventories increased nearly 10%, as did worldwide inventories of elemental sulfur. *(See table 1 and figure 1.)*

Production

Elemental Sulfur.—Production was slightly lower than that of 1995. Shipments were slightly lower in quantity and 23% lower in value owing to a substantial decrease in the average price of elemental sulfur.

Production statistics are collected on a monthly basis and published in the USGS sulfur monthly Mineral Industry Surveys. Of the 139 operations to which survey requests were sent, all but 1 responded, representing nearly 100% of the total production shown in table 1. Production data for the nonrespondent was obtained from the State of Texas (Texas Comptroller of Public Accounts, 1997).

Frasch.—Native sulfur associated with the caprock of salt domes and in sedimentary deposits is mined by the Frasch hot-water method, in which the native sulfur is melted underground and brought to the surface by compressed air. Freeport Sulphur Co. operated two Frasch mines, one each in Louisiana and Texas. Freeport's operations included the Culberson Mine in west Texas; sulfur-forming and sulfur-loading facilities in Galveston, TX, and Tampa, FL; and the Main Pass Mine, 27 kilometers offshore Louisiana in the Gulf of Mexico. Production at Main Pass and Culberson averaged about 5,440 and 2,490 tons per day, respectively, throughout the year (Freeport McMoRan Resource Partners, 1997, p. 4).

Recovered.—Recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered elemental sulfur was produced by 59 companies at 137 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the U.S. Virgin Islands. Most of these plants were of relatively small size, with only 26 reporting annual production exceeding 100,000 tons. By source, 72% was produced at petroleum refineries or satellite plants treating refinery gases and coking plants. The remainder was produced at natural gas treatment plants. The largest recovered-sulfur producers were Exxon Co. U.S.A., Standard Oil Co. (Indiana), Standard Oil Co. (California), Mobil Oil Corp., Star Enterprises, and Shell Oil Co. The 47 plants owned by these companies accounted for 58% of recovered elemental sulfur output during the year. *(See tables 2 and 3.)*

Byproduct Sulfuric Acid.—Production at copper, lead,

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molybdenum, and zinc roasters and smelters amounted to 12% of the total domestic production of sulfur in all forms. Seven acid plants operated in conjunction with copper smelters, and six were accessories to lead, molybdenum, and zinc smelting and roasting operations. The seven largest acid plants (all at copper mines) accounted for 87% of the output. The largest producers—Phelps Dodge Corp., Broken Hill Proprietary Co., Ltd. (formerly Magma Copper Co.), ASARCO Incorporated, Cyprus Miami Mining Corp., and Kennecott Corp.—operated seven copper plants. *(See table 4 and figure 2.)*

Consumption

Domestic consumption of sulfur in all forms was about 8% lower than that of 1995. Of the sulfur consumed, 83% was obtained from such domestic sources as elemental sulfur (72%) and byproduct acid (11%) compared with 78% in 1995 and 77% in 1994. The remaining 17% was supplied by imports of recovered elemental sulfur (12%) and sulfuric acid (5%). The USGS collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities.

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The largest sulfur end use, sulfuric acid, represented 86% of reported consumption with an identified end use. Some identified sulfur end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as "Unidentified." Although there are no supporting data, it could be reasonably assumed that a significant portion of the sulfur in the "Unidentified" category was shipped to sulfuric acid producers or was exported.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed, by volume, inorganic chemical. Reported U.S. consumption of sulfur in sulfuric acid (100% basis) decreased in 1996, primarily owing to the decrease in sulfur used in the production of phosphatic fertilizers. Although reported data for total sulfur consumption indicated a slight increase, apparent consumption figures indicate that actual consumption was probably lower than that of 1995.

Agriculture was the largest sulfur-consuming industry despite a decrease to 8.4 million tons compared with 9 million tons reported in 1995. Reported consumption in phosphatic fertilizers was 10% lower than that of 1995, reflecting decreased production and temporary shutdowns at a number of phosphoric acid plants. Actual consumption for phosphate fertilizer probably did not decrease that much because some or most of the "Unidentified" sulfur consumption is believed to have been for that end use. On the basis of export data from the Bureau of the Census, the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers decreased 14% to 4.9 million tons; reports from the Fertilizer Institute, however, stated that the reported phosphate fertilizer exports were believed to be understated, and the Department of Commerce was conducting an investigation to resolve the problem (Vrooman, 1997).

The second largest end use for sulfur was in petroleum refining and other petroleum and coal products. On the basis of events in the petroleum refining industry, an increase in petroleum refining uses would be expected; the significant increases reported for the use of elemental sulfur in this category, however, indicate inconsistencies in reporting. Demand for sulfuric acid in copper ore leaching, the third largest end use, decreased 8%. *(See tables 5, 6, and 7.)*

According to the 1996 canvass reports, company receipts of spent or contaminated sulfuric acid for reclaiming totaled 1.8 million tons. This figure was believed to be significantly higher than reported; most of the acid is, however, recycled by companies that produce acid for consumption in their own operations and also recycle acid used in their plants. Because it does not involve sales or shipments of the spent sulfuric acid, many companies do not handle the acid recycling as a separate process and thus do not report it in the USGS consumption survey. The petroleum refining industry is believed to be the largest source and consumer of recycled acid for use in its alkylation process.

Stocks

Yearend inventories held by Frasch and recovered elemental sulfur producers increased nearly 10% from those of 1995. On the basis of apparent consumption of all forms of sulfur, combined yearend stocks amounted to approximately an 18-day supply compared with a 15-day supply in 1995 and a 32-day supply in 1994. *(See table 1.)*

Prices

The reported contract prices for elemental sulfur, exterminal Tampa, FL, began the year at $74 to $77 per ton, decreased incrementally until they reached a low of $59 to $61 in early July, rose to $61 to $63 per ton at the end of October, and remained steady through the remainder of the year. On the basis of total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was $34.48 per ton, which was 21% lower than that of 1995.

Foreign Trade

Exports of elemental sulfur from the United States, including the U.S. Virgin Islands, were about 6% lower than those of 1995 and 22% lower in value because of significant price decreases for U.S. material. The average unit value of exported elemental sulfur decreased from $73 per ton to $65, a decrease of 17%. According to the Bureau of the Census, exports from the west coast were 685,000 tons, or 80% of total U.S. exports.

The United States continued to be a net importer of sulfur—

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imports exceeded exports by 765,000 tons. Recovered sulfur from Canada and Mexico delivered to U.S. terminals and consumers in the liquid phase furnished about 93% of all U.S. sulfur import requirements. Total elemental sulfur imports decreased about 35% in quantity; imports by rail from Canada decreased 35%, and waterborne shipments from Mexico were 11% lower than those of 1995. Imports from several other countries comprised about 17% of all imported sulfur. The value of elemental sulfur imports decreased 58%.

Imports from Canada were significantly lower because of the low prices. In such a situation, Canadian producers may limit their shipments to the United States to avoid the possibility of an antidumping complaint. The U.S. Department of Commerce (DOC) completed an investigation concerning a complaint of this type against Canadian sulfur producers filed by Pennzoil Sulphur Co. in 1994 regarding the period from December 1, 1992, to November 30, 1993. DOC found that sales were made at discounts ranging from 11.79% to 42.8%. Antidumping duties were assessed against the companies in question (Green Markets, 1996).

The United States also had significant trade in sulfuric acid. Sulfuric acid exports decreased 31% from those of 1995. Acid imports were 10 times greater than exports. Canada was the source of 77% of U.S. acid imports, most of which were probably byproduct acid from smelters. Canadian shipments to the U.S. were shipped by rail. The remainder came primarily by ship from Europe, Latin America, and Japan. The tonnage increased 8% from that of 1995; the value of imported sulfuric acid decreased by 16%. *(See tables 8, 9, 10, and 11.)*

World Review

World production was slightly lower than that of 1995; consumption was believed to be about the same. Prices were down. Cutbacks were made at U.S. and Polish Frasch operations to maintain a better supply/demand balance worldwide. Recovered sulfur production and byproduct sulfuric acid production were virtually unchanged. Even with slightly decreased production, supply surpassed demand; worldwide sulfur inventories increased to 16.2 million tons, of which 60% was stockpiled in Canada.

Industry Structure.—The global sulfur industry remained divided into two sectors. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of native sulfur or pyrites is based on the orderly mining of discrete deposits, with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct, the quantity of output subject to demand for the primary product irrespective of sulfur demand. Nondiscretionary sources represented about 76% of the sulfur in all forms produced worldwide.

Poland and the United States were the only countries that produced 1 million tons or more of native sulfur by using either the Frasch method or conventional mining methods. Small quantities of native sulfur were produced in Asia, Europe, North America, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China and Spain were the only countries in the top 15 sulfur producers whose primary sulfur source was pyrites. About 71% of all pyrites production was in these countries.

Recovered elemental sulfur was the predominant source of sulfur in Canada, France, Germany, Iran, Russia, Saudi Arabia, and the United States. Additionally, recovered elemental sulfur was an important source in Japan and Mexico.

International sulfur trade was dominated by a limited number of exporting countries. Canada, Saudi Arabia, Poland, and Germany, in descending order of importance, exported more than 1 million tons of elemental sulfur each and accounted for 64% of sulfur trade. Major sulfur importers, in descending order, were Morocco, the United States, India, Tunisia, and Brazil, all with imports of more than 1 million tons.

Australia.—Sulfuric acid production in Australia in 1996 was more than 1.2 million tons from smelters and 330,000 tons from one plant burning elemental sulfur. Most of the acid was used for the production of fertilizers, and additional sulfuric acid requirements were met through imports. Metal leaching was expected to be a growth area for sulfur consumption, especially in Western Australia. Three nickel-leaching projects were under consideration. Two of the projects would use acid purchased from a sulfuric acid plant that was completed in late 1996 at a nickel smelter in Kalgoorlie, and the other would produce its own acid from elemental sulfur. Initial production from the Kalgoorlie plant was expected to be exported (Wellington, 1996).

A large sulfuric acid plant was planned in conjunction with the Mount Isa Mines Ltd. copper smelter in Queensland. Upon completion, the operation will have the capacity to recover 1.2 million tons of sulfuric acid per year with an expected annual production of 800,000 tons. Full commissioning of the sulfuric acid plant was expected in early 2000. The acid will provide the necessary acid imports for the new Queensland Fertilizer Project about 150 kilometers south of Mount Isa (Sulphur, 1997).

The Queensland plant was not considered to be a possible source of acid for the Western Australia nickel projects because the cost of shipping across the country would be prohibitive.

Canada.—Second only to the United States in sulfur production in all forms, Canada led the world in the production of byproduct sulfur, exports of elemental sulfur; and stockpiled material. Canadian stocks were 9.7 million tons at the end of 1996, an increase of 15% from those of the previous year (Prud'homme, 1997).

There were 48 sulfur recovery operations at natural gas processing plants in Alberta and 5 in British Columbia. Most Canadian sulfur production was in these provinces, and production continued to expand. The capacity for sulfur recovery in these provinces was nearly 35,000 tons per day, a figure that translates into an annual capacity of almost 16 millions tons per year of sulfur from natural gas processing alone. Additional sulfur was recovered from oil sands in these provinces. Although sulfur recovery from oil sands is less than

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10% of total Canadian sulfur production, the potential of further development of the vast oil sands reserves presents the possibility of a further 10 million tons per year of Canadian supply. Investigations were being conducted into alternative methods of dealing with the sulfur from these processes in the hope of finding a technology, perhaps reinjection, that reduces the amount of sulfur that results from sour gas and oil sands processing (Horseman, 1996).

Byproduct sulfuric acid from metal smelters was a predominant source of sulfur in other forms. Small in comparison to the quantity of sulfur produced in elemental form, smelter acid represents further growth for sulfur production in all forms. Increases in smelter acid production were expected from improvements at existing operations and a new nickel smelter in Newfoundland to be completed in 2000 or 2001 (Prud'homme, 1997).

China.—China was the leading producer and consumer of pyrites as the source of sulfur for sulfuric acid production. Indications were, however, that China was beginning to turn to imported elemental sulfur as an alternative raw material. Canada and Japan were the primary suppliers of the elemental sulfur. Continued growth was expected in this market (Sulphur, 1996a).

Iraq.—Although Iraqi sulfur production did not have an impact on the world market, the potential exists for the country to return to its role as a leading exporter when the United Nations sanctions are lifted. Sulfur production capacity at the Mishraq Mine was believed to be more than 1 million tons per year. When sanctions are lifted, production, much of which would be exported, is expected to approach full capacity quickly.

Kazakstan.—Tengizchevroil, established in 1993 as a joint oil and gas venture of Tengizmunaigaz, the government-owned gas and oil company, and Chevron Overseas Co., a division of Chevron Corp., developed the Tengiz oil field, the largest oil field discovered in the world in the last 20 years. Mobil became a 25% partner in the project in 1996.

Located on the southern side of the North Caspian Basin, Tengiz reserves were estimated to be more than 3 billion tons of crude oil and 1,800 billion cubic meters of associated gas, both of which have high hydrogen sulfide contents, thus necessitating sulfur removal. The field was discovered in 1979, but the high sulfur content delayed its development until technology was developed that could successfully treat the high sulfur-content gas concentrates. In late 1996, the fourth 250,000-ton-per-year sulfur recovery unit was completed, bringing the sulfur recovery capacity to 1 million tons per year. Total sulfur recovery at the project is 99% or higher.

Marketing Tengiz products was difficult because Kazakstan's infrastructure was inadequate to support full production at the oil field. The situation had improved by the end of 1996, and much of the oil was reaching markets in Russia and Finland. Sulfur was shipped via Tengizchevroil's fleet of rail tank cars or stockpiled. Sulfur-crushing operations were suspended because of safety and environmental concerns (Freter, 1997). Agreements were reached between the governments of Kazakstan, Oman, and Russia and a number of international oil companies to expand the Russian oil pipeline system to transport Tengiz oil to the port of Novorossiisk on the Black Sea. Tengiz oil production was estimated to be 4.4 million tons, and the partnership planned to expand production to 50 million tons by 2000. The pipeline from Tengiz was essential to fulfilling these expectations. Sulfur production in 1996 was estimated to be about 500,000 tons (Sulphur, 1996b).

Because sulfur sales from Tengiz have been difficult owing to the distances the material must be transported to reach major markets, research was being conducted to identify domestic markets. Possible markets were toxic and hazardous waste stabilization, transportation infrastructure improvements with sulfur paving materials, other construction applications, and reclamation of sodic soils to improve agricultural productivity (Kalb and others, 1996).

Poland.—One of the few remaining producers of native sulfur, Polish Frasch production was 45% lower than that of 1992, the year when production was highest. Further cuts were planned for 1997, which could reduce planned production to 1.2 million tons. These reductions were necessary because the high cost of Frasch production made Polish sulfur prices uncompetitive in world markets. Plans were progressing for privatization of Ciech AgroSulphur, the government-owned sulfur trading company (Sulphur, 1997). *(See table 12.)*

Outlook

The longer term outlook for the sulfur industry was unchanged—increased output with slower growth in consumption resulting in variable prices and growing inventories. Specific details are much more difficult to predict. Which producers will suffer most from the oversupply situation is a question that can be answered only over time.

World sulfur demand is forecast to increase at an annual rate of about 2% per year for the next 10 years. World demand is projected to approach 60 million tons in 2001 and increase to nearly 67 million tons in 2006. Growth of sulfur consumption in the United States is expected to be modest. The phosphate fertilizer industry has not announced expansions; expectations for growth will reflect only slight improvements in efficiency at operating plants and periodic changes in production caused by opening and closing of marginal facilities in response to market conditions. Industrial consumption should remain fairly steady with the only serious possibility of increases in nonferrous ore leaching.

Almost 66% of sulfur consumption in the United States was for agricultural uses. More than 80% of U.S. agricultural sulfur demand and almost 60% of world agricultural sulfur consumption were for the manufacture of phosphoric acid. World demand for phosphate fertilizers is forecast to increase at a rate of about 2.7% per year for the next 10 years. It is assumed that more than 80% of the growth will be for the production of phosphoric acid to produce high-analysis fertilizers; the increased production will directly affect world sulfur demand. Consumption of sulfur for phosphate fertilizer

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manufacture in the United States is divided into two components—demand for phosphate fertilizers consumed by domestic farmers and demand for exported phosphate fertilizers. Fertilizer consumption is reasonably stable, and exports are expected to remain strong.

The broad-spectrum industrial or nonagricultural sulfur use category accounted for less than 33% of U.S. sulfur consumption and about 40% of world sulfur demand. Although significant variations in demand for the diverse elements within this broad category are expected in the United States and other geographic areas, world industrial demand is expected to grow at an average rate of 1.1% per year during the next 10 years, reaching about 29 million tons.

The necessity for the removal of sulfur from solid, liquid, and gaseous effluents for environmental protection has caused the production of sulfur and sulfur compounds from these sources to exceed production from primary sources of supply. The long-term prospect is that 85% or more of the world sulfur supply will come from environmentally regulated sources and that output from these sources will be produced regardless of world sulfur demand. As a result, it is probable that no new operation that produces sulfur as its primary product will be developed and that more voluntary operations will be curtailed. In 1980, voluntary sources of production—Frasch, native sulfur, and pyrites—accounted for 50% of the world output of about 55 million tons. In 1996, these same sources supplied only 24% of the world production of 52.4 million tons.

Voluntary production of sulfur should continue to decline while recovered sulfur production will continue to expand at a faster pace than demand. As more countries enact and enforce environmental legislation on a par with North American and European laws, tremendous new quantities of sulfur could be recovered. More-stringent regulation and compliance will be long-term developments and cannot be quantified at the current time, but changes are inevitable. In fact, the impact of projects to improve sulfur recovery, especially at copper smelters, is already being felt. World sulfur production is predicted to reach nearly 64 million tons in 2001 and 68 million tons in 2006.

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[1]Prior to January 1996, published by U.S. Bureau of Mines.

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TABLE 1
SALIENT SULFUR STATISTICS 1/

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production:					
Frasch	2,320	1,900 2/	2,960 e/	3,150 e/	2,900 e/
Recovered 3/	7,050	7,720 4/	7,160 e/	7,250	7,470
Other forms	1,300	1,430	1,380	1,400	1,430
Total	10,700	11,100	11,500 e/	11,800 e/	11,800 e/
Shipments:					
Frasch	2,600	1,480 2/	W	W	W
Recovered 3/	7,090	7,580 4/	10,300 5/	10,700 5/	10,400 5/
Other forms	1,300	1,430	1,390	1,400	1,430
Total	11,000	10,500	11,700	12,100	11,800
Exports:					
Elemental 6/	966	656	899	906	855
Sulfuric acid	46	46	46	56	38
Imports:					
Elemental	2,730	2,040	1,650	2,510	1,620
Sulfuric acid	649	797	696	628	678
Consumption, all forms	13,400	12,600	13,100	14,300 r/	13,200
Stocks, Dec. 31: Producer, Frasch and recovered	809	1,380	1,160	583	639
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$151,000	$101,000	W	W	W
Recovered 3/	$315,000	$189,000	$293,000 5/	$469,000 5/	$359,000 5/
Other forms	$76,100	$63,100	$86,100	$85,500	$85,900
Total	$543,000	$335,000	$379,000	$555,000	$445,000
Exports, elemental 6/ 7/	$69,700	$39,700	$48,400	$66,200	$51,700
Imports, elemental	$130,000	$49,800	$62,000	$143,000	$60,500
Price, elemental, dollars per metric ton, f.o.b. mine or plant	$48.14	$31.86	$28.60	$43.74	$34.48
World: Production, all forms (including pyrites)	50,700	51,200 r/	53,700 r/	53,200 r/	52,400 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Recovered."

1/ Data are rounded to three significant digits except prices.

2/ Includes 10 months of Frasch sulfur data. Two remaining months of Frasch data included with "Recovered" to avoid disclosing company proprietary data.

3/ Includes Puerto Rico and the U.S. Virgin Islands.

4/ Includes corresponding Frasch sulfur data for November and December.

5/ Includes corresponding Frasch sulfur data.

6/ Includes exports from the U.S. Virgin Islands to foreign countries.

7/ Includes value of exports from the U.S. Virgin Islands to foreign countries.

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TABLE 2
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE 1/

(Thousand metric tons and thousand dollars)

State	1995			1996		
		Shipments			Shipments	
	Production	Quantity	Value	Production	Quantity	Value
Alabama	396	396	17,500	398	400	14,100
California	800	804	13,200	828	834	6,080
Illinois	331	331	14,700	353	351	8,700
Louisiana	789	W	W	877	W	W
Michigan and Minnesota	258	258	7,060	254	255	749
Mississippi	550	557	12,100	471	468	10,800
New Mexico	41	41	576	44	44	252
North Dakota	57	57	538	50	50	288
Ohio	60	60	2,090	68	68	1,680
Pennsylvania	51	51	1,360	W	W	W
Texas	2,090	2,970 2/	144,000 2/	2,230	3,180 2/	122,000 2/
Washington	114	113	1,330	112	113	899
Wyoming	1,030	1,020	13,700	1,080	1,060	23,600
Other 3/	682	4,060	241,000	706	3,590	170,000
Total	7,250	10,700	469,000	7,470	10,400	359,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes corresponding Frasch sulfur data.

3/ Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Louisiana (shipments and value), Montana, New Jersey, Utah, Virginia, Wisconsin, Puerto Rico, and the U.S. Virgin Islands.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES,
BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT 1/

(Thousand metric tons)

District and source	1995		1996	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	245	238	217	225
Natural gas	50	50	51	51
Total	295	288	267	276
PAD 2:				
Petroleum and coke	904	899	927	925
Natural gas	58	58	50	49
Total	962	957	977	975
PAD 3: 2/				
Petroleum and coke	2,860	W	3,140	W
Natural gas	1,100	W	982	W
Total	3,970	7,400 3/	4,120	7,070 3/
PAD 4 and 5:				
Petroleum and coke	1,030	1,030	1,090	1,100
Natural gas	999	994	1,010	992
Total	2,030	2,030	2,100	2,090
Total petroleum	5,040	W	5,370	W
Total natural gas	2,210	W	2,090	W
Grand total	7,250	10,700 3/	7,470	10,400 3/

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes Puerto Rico and the U.S. Virgin Islands.

3/ Includes corresponding data from Frasch producers.

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TABLE 4
BYPRODUCT SULFURIC ACID 1/ PRODUCED
IN THE UNITED STATES 2/

(Thousand metric tons, sulfur content, and thousand dollars)

Type of plant	1995	1996
Copper 3/	1,210	1,240
Zinc 4/	118	118
Lead and molybdenum 4/	70	68
Total	1,400	1,430
Value	85,500	85,900

1/ Includes acid from foreign materials.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Excludes acid made from pyrites concentrates.
4/ Excludes acid made from native sulfur.

TABLE 5
CONSUMPTION OF SULFUR 1/ IN THE UNITED STATES 2/

(Thousand metric tons)

	1995	1996
Total elemental:		
Shipments 3/	10,700	10,400
Exports	906	855
Imports	2,510 r/	1,620
Total	12,300 r/	11,200
Byproduct sulfuric acid:		
Shipments 3/	1,400	1,430
Exports 4/	56	38
Imports 4/	628	678
Total, all forms	14,300 r/	13,200

r/ Revised.
1/ Crude sulfur or sulfur content.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Includes Puerto Rico and the U.S. Virgin Islands.
4/ May include sulfuric acid other than byproduct.

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TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE 1/

(Thousand metric tons, sulfur content)

SIC 3/	End use	Elemental sulfur 2/ 1995	Elemental sulfur 2/ 1996	Sulfuric acid (sulfur equivalent) 1995	Sulfuric acid (sulfur equivalent) 1996	Total 1995	Total 1996
102	Copper ores	--	--	864 r/	798	864 r/	798
1094	Uranium and vanadium ores	--	--	2 r/	2	2 r/	2
10	Other ores	--	--	93	57	93	57
26, 261	Pulpmills and paper products	W	W	319 r/	343	319 r/	343
28, 285, 286, 2816	Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products 4/	34	67	170 r/	152	204 r/	219
281	Other inorganic chemicals	132	128	167 r/	154	299 r/	282
282, 2822	Synthetic rubber and other plastic materials and synthetics	W	W	245 r/	270	245 r/	270
2823	Cellulosic fibers, including rayon	--	--	50	47	50	47
283	Drugs	--	--	4	4	4	4
284	Soaps and detergents	9	9	12	19	21	28
286	Industrial organic chemicals	--	--	57 r/	48	57 r/	48
2873	Nitrogenous fertilizers	--	--	88	142	88	142
2874	Phosphatic fertilizers	--	--	8,200	7,380	8,200	7,380
2879	Pesticides	--	--	10	10	10	10
287	Other agricultural chemicals	673	824	29	27	702	851
2892	Explosives	--	--	3	5	3	5
2899	Water-treating compounds	--	--	74 r/	91	74 r/	91
28	Other chemical products	--	--	41	41	41	41
29, 291	Petroleum refining and other petroleum and coal products	395	739	479 r/	525	874 r/	1,260
30	Rubber and miscellaneous plastic products	W	W	--	--	W	W
331	Steel pickling	--	--	7	8	7	8
333	Nonferrous metals	--	--	8	7	8	7
33	Other primary metals	--	--	1	1	1	1
3691	Storage batteries (acid)	--	--	25	33	25	33
	Exported sulfuric acid	--	--	10	6	10	6
	Total identified	1,240	1,770	11,000 r/	10,200	12,200 r/	11,900
	Unidentified	533	807	508 r/	780	1,040 r/	1,590
	Grand total	1,780	2,570	11,500 r/	11,000	13,200 r/	13,500

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Does not include elemental sulfur used for production of sulfuric acid.
3/ Standard Industrial Classification.
4/ No elemental sulfur was used in inorganic pigments and paints and allied products.

TABLE 7
SULFURIC ACID FROM SMELTERS SOLD OR USED IN THE UNITED STATES, BY END USE 1/

(Thousand metric tons of 100% H_2SO_4)

SIC 2/	Use	1995	1996
102	Copper ores	2,250	2,360
10	Other ores	W	W
26, 261	Pulp mills and other paper products	52 r/	47
28, 281, 282, 283, 286, 2816	Miscellaneous chemicals	143	87
2873	Nitrogenous fertilizers	48	58
2874	Phosphatic fertilizers	505 r/	417
287, 2879	Pesticides and other agricultural chemicals	84	86
2899	Water-treating compounds	76	80
291	Petroleum refining	W	W
3691	Storage batteries (acid)	W	W
33, 331, 333, 1094	Miscellaneous metal usage	23	25
	Unidentified 3/	881 r/	1,190
	Total	4,060 r/	4,340

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Standard Industrial Classification.
3/ Includes exports.

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TABLE 8
U.S. EXPORTS 1/ OF ELEMENTAL SULFUR, BY COUNTRY 2/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value	Quantity	Value
Argentina	36	2,130	4	537
Australia	23	3,250	29	3,450
Bangladesh	26	1,280	--	--
Brazil	116	6,690	50	2,260
Canada	29	4,070	65	6,010
Colombia	9	721	9	668
India	178	9,020	(3/)	4
Indonesia	85	4,530	(3/)	11
Korea, Republic of	27	9,750	4	5,690
Mexico	64	4,540	139	7,370
Morocco	33	1,460	--	--
Senegal	187	9,980	194	7,300
South Africa	1	185	1	302
Tunisia	33	1,320	97	3,280
Other	59	7,240	263	14,900
Total	906	66,200	855	51,700

1/ Includes exports from the U.S. Virgin Islands.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 9
U.S. EXPORTS OF SULFURIC ACID (100% H2SO4), BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	1,000	$116	28	$3
Canada	64,300	4,890	70,200	5,280
China	1,250	225	2,160	464
Costa Rica	697	141	361	18
Dominican Republic	4,570	280	2,550	178
Israel	13,300	858	1,460	433
Japan	630	182	462	144
Korea, Republic of	914	44	204	36
Mexico	45,000	2,310	6,550	930
Netherlands	2,270	78	4,580	245
Netherlands Antilles	5,650	237	12	4
Panama	3,900	156	1,180	57
Saudi Arabia	1,200	64	143	18
Singapore	1,910	380	734	437
Taiwan	3,530	814	497	293
Trinidad and Tobago	5,110	365	7,270	430
United Kingdom	(2/)	3	237	39
Uruguay	3,500	158	--	--
Venezuela	7,550	325	1,520	173
Other	3,880	1,210	17,300	3,170
Total	170,000	12,800	117,000	12,400

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 10
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY 1/

(Thousand metric tons and thousand dollars)

Country	1995		1996	
	Quantity	Value 2/	Quantity	Value 2/
Canada	1,630	63,200	1,060	30,400
Mexico	506	29,300	448	21,200
Other	377	50,000	112	8,970
Total	2,510	143,000	1,620	60,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared customs valuation.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS OF SULFURIC ACID (100% H2SO4), BY COUNTRY 1/

Country	1995		1996	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Argentina	3,600	$1,660	2,840	$373
Canada	1,660,000	75,600	1,600,000	59,600
Chile	20,900	462	--	--
Germany	94,400	4,720	167,000	5,630
Japan	23,600	1,930	127,000	5,220
Mexico	95,300	8,540	138,000	5,760
Netherlands	(3/)	10	16,800	400
Spain	--	--	25,800	889
United Kingdom	670	--	78	23
Other	22,700	40	673	123
Total	1,920,000	92,900 r/	2,070,000	78,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Declared c.i.f. (cost, insurance, and freight paid by shipper) valuation.
3/ Less than 1/2 unit.

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TABLE 12
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1992	1993	1994	1995	1996 e/
Canada: Byproduct:					
Metallurgy	931	900	870	860	883 p/
Natural gas	5,769	6,600	7,000	7,100	7,070
Petroleum	235	340	350	380	650
Tar sands	552	590	630	670	407
Total	7,487	8,430	8,850	9,010	9,014 p/
China: e/					
Native	320	330	330	160 r/	170
Pyrites	4,930	5,330	5,870	4,570 r/	4,600
Byproduct, all sources	650	700	700	700	700
Total	5,900	6,360	6,900	5,430 r/	5,470
France: Byproduct:					
Natural gas	770	829	865	825 r/	850
Petroleum	230	278	219	240 r/	250
Unspecified e/	150	150	100	100	100
Total e/	1,150	1,260	1,180	1,170 r/	1,200
Germany:					
Pyrites e/	25	--	--	--	--
Byproduct:					
Metallurgy	23	33	35 e/	20 r/	20
Natural gas and petroleum	1,016	1,137	880 r/	1,000 r/	1,000
Unspecified e/ 4/	100 5/	90	90	90	90
Total e/	1,160	1,261 r/ 5/	1,010 r/	1,110 r/	1,110
Iran: Byproduct: e/					
Metallurgy	50	50	50	50	50
Natural gas and petroleum	700	750	830	840	840
Total	750	800	880 5/	890	890
Iraq: e/					
Frasch	250	250	250	250	250
Byproduct, natural gas and petroleum	100	200	225	225	225
Total	350	450	475	475	475
Japan:					
Pyrites	31	29	4	2 e/	2
Byproduct:					
Metallurgy	1,374	1,383	1,269	1,310 r/	1,300
Petroleum	1,340	1,510	1,550 e/	1,500 e/	1,500
Total	2,745	2,922	2,820 e/	2,810 r/ e/	2,800
Mexico:					
Frasch	710	102	--	--	--
Byproduct:					
Metallurgy e/	817	730	2,014 5/	2,000	2,000
Natural gas and petroleum	775	804	877	882	885
Total e/	2,300	1,640	2,890	2,880	2,890
Poland: 6/					
Frasch	2,329 r/	1,861 r/	2,163 r/	2,425 r/	1,530
Native	562	--	--	--	--
Byproduct:					
Metallurgy	207	220	200 e/	200 e/	200
Petroleum	26	29	25 e/	25 e/	25
Gypsum e/	10	10	10	10	10
Total	3,134 r/	2,120 r/	2,398 r/	2,660 r/ e/	1,769 5/
Russia: e/ 7/					
Native	100	100	80	80	70
Pyrites	390	640	700	750	750
Byproduct, natural gas	2,830	2,680	2,550	2,970	3,000
Other	175	180	175	200	200
Total	3,500	3,600	3,510	4,000	4,020
Saudi Arabia: Byproduct, all sources	2,370	2,400	2,300	2,200	2,000
South Africa:					
Pyrites	296	323	252	159	193
Byproduct:					
Metallurgy	56 e/	81 e/	118	67 r/	80
Petroleum 8/	166	171	209	233	196
Total	518	575	579	459 r/	469

See footnotes at end of table.

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TABLE 12--Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE 1/ 2/

(Thousand metric tons)

Country and source 3/	1992	1993	1994	1995	1996 e/
Spain:					
Pyrites	535 r/	408 r/	436 r/	404 r/	400
Byproduct: e/					
Coal (lignite) gasification	2	2	2	2	2
Metallurgy	258	258	250	250	250
Petroleum	90	100	100	100	100
Total e/	885 r/	768 r/	788 r/	756 r/	752
United States:					
Frasch	2,320	1,900 9/	2,930 e/	3,150 e/	2,900
Pyrites	W	W	(10/)	(10/)	(10/)
Byproduct:					
Metallurgy	1,290	1,430	1,380	1,400	1,430 5/
Natural gas	2,530	2,910 r/ 11/	2,240	2,210	2,100 5/
Petroleum	4,520	4,820	4,920	5,040	5,370 5/
Unspecified	3	3	(10/)	(10/)	(10/)
Total	10,700	11,100 r/	11,500 e/	11,800 e/	11,800
Other countries:	7,778 r/	7,622 r/	7,619 r/	7,526 r/	7,550
Of which:					
Frasch	18	22 r/	21 r/	22 r/	23
Native	1,000	789	618 r/	503 r/	493
Pyrites	1,649 r/	1,297 r/	1,202 r/	1,097 r/	1,060
Byproduct:					
Metallurgy	2,154 r/	2,249 r/	2,213 r/	2,225 r/	2,200
Natural gas	385	390 r/	348	397 r/	398
Natural gas and petroleum, undifferentiated	355	455	794	888	962
Petroleum	1,360 r/	1,542 r/	1,548 r/	1,513 r/	1,540
Unspecified sources	857	879	876 r/	881 r/	875
Grand total	50,700	51,300 r/	53,700 r/	53,200 r/	52,200
Of which:					
Frasch	5,630 r/	4,140	5,360 r/	5,850 r/	4,710
Native	1,980	1,220	1,030	743 r/	733
Pyrites	7,860 r/	8,030 r/	8,460 r/	6,980 r/	7,000
Byproduct:					
Coal (lignite) gasification e/	2	2	2	2	2
Metallurgy	7,160 r/	7,330 r/	8,400 r/	8,380 r/	8,410
Natural gas	12,300	13,400 r/	13,000	13,500 r/	13,400
Natural gas and petroleum, undifferentiated	2,950	3,350	3,610 r/	3,840 r/	3,910
Petroleum	7,970 r/	8,790 r/	8,930 r/	9,030 r/	9,630
Tar sands	552	590	630	670	407
Unspecified sources	4,300	4,400 r/	4,240 r/	4,170 r/	3,970
Gypsum e/	10	10	10	10	10

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Byproduct: Unspecified sources."

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 4, 1997.

3/ The term "Source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery, (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch), (3) pyrites (whether or not the sulfur is recovered in the elemental form or as acid), (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers, and (5) recovery from the processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which, in some instances, is not the original source country of the crude product from which the sulfur is extracted.

4/ Data for 1992 represent byproduct production from the eastern states. Production data for 1993-96 represent those of the unified country.

5/ Reported figure.

6/ Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

7/ Sulfur is believed to be produced from Frasch and pyrite and as a petroleum byproduct; however, information is inadequate to formulate estimates.

8/ Includes byproduct production from synthetic fuels.

9/ Includes 10 months of Frasch sulfur production data. Two remaining months of Frasch data included with byproduct natural gas data to conform with proprietary data requirements.

10/ Survey discontinued in 1994; data not available.

11/ Includes Frasch sulfur production data for November and December.

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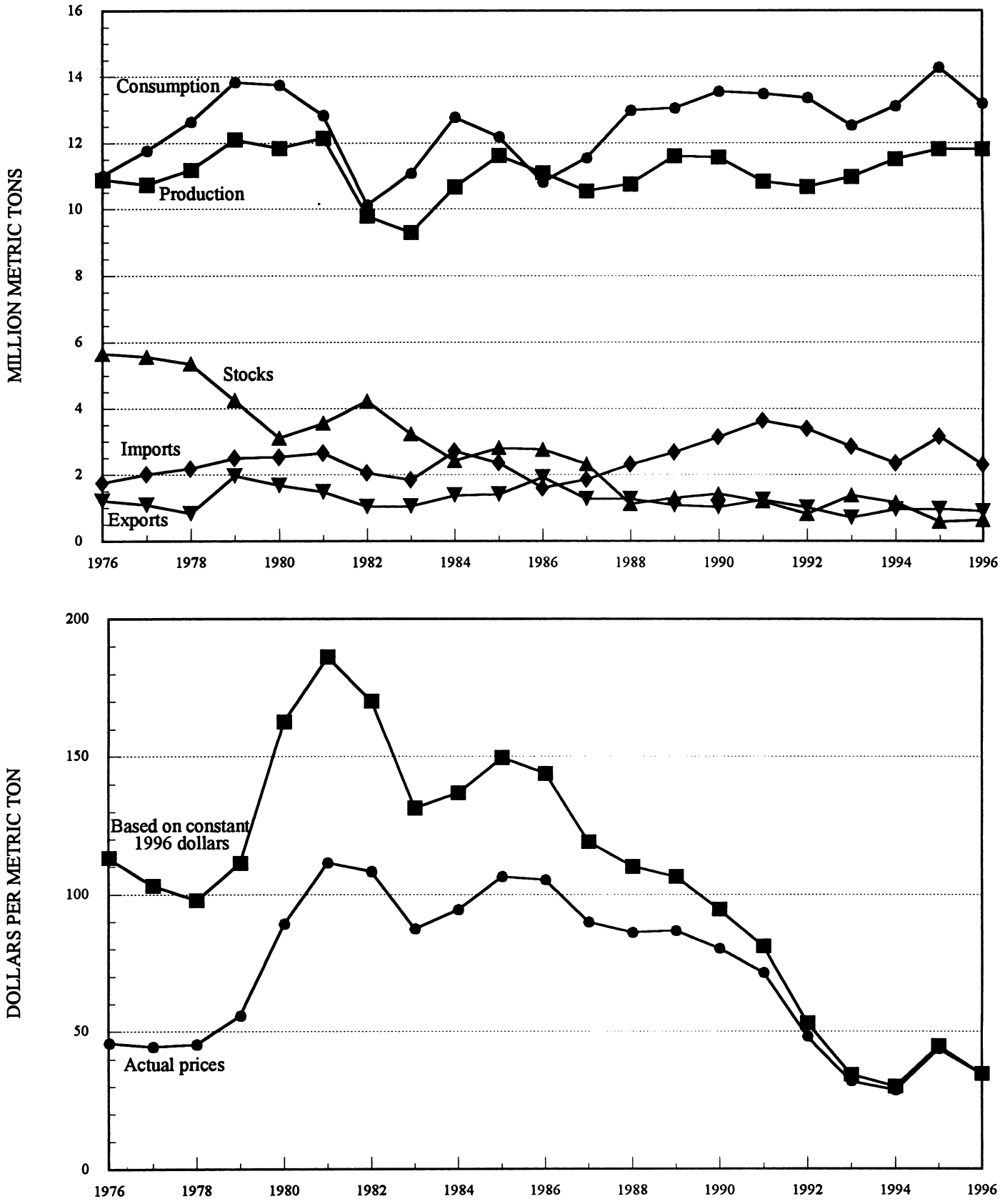
Figure 1

TRENDS IN THE SULFUR INDUSTRY IN THE UNITED STATES



Based on the average reported values for elemental sulfur (Frasch and recovered), f.o.b. mine and/or plant, these prices reflect about 90% of the shipments of sulfur in all forms from 1976 through 1996.

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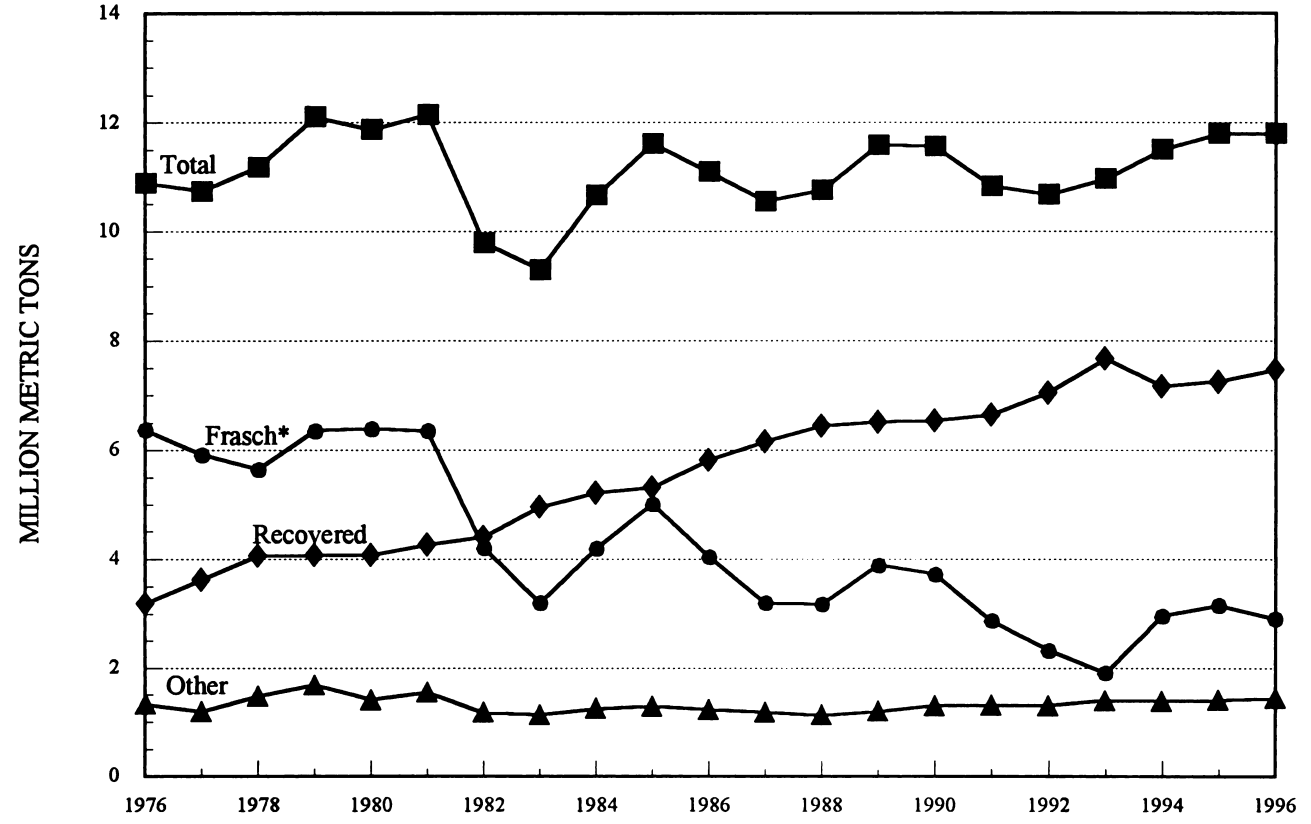
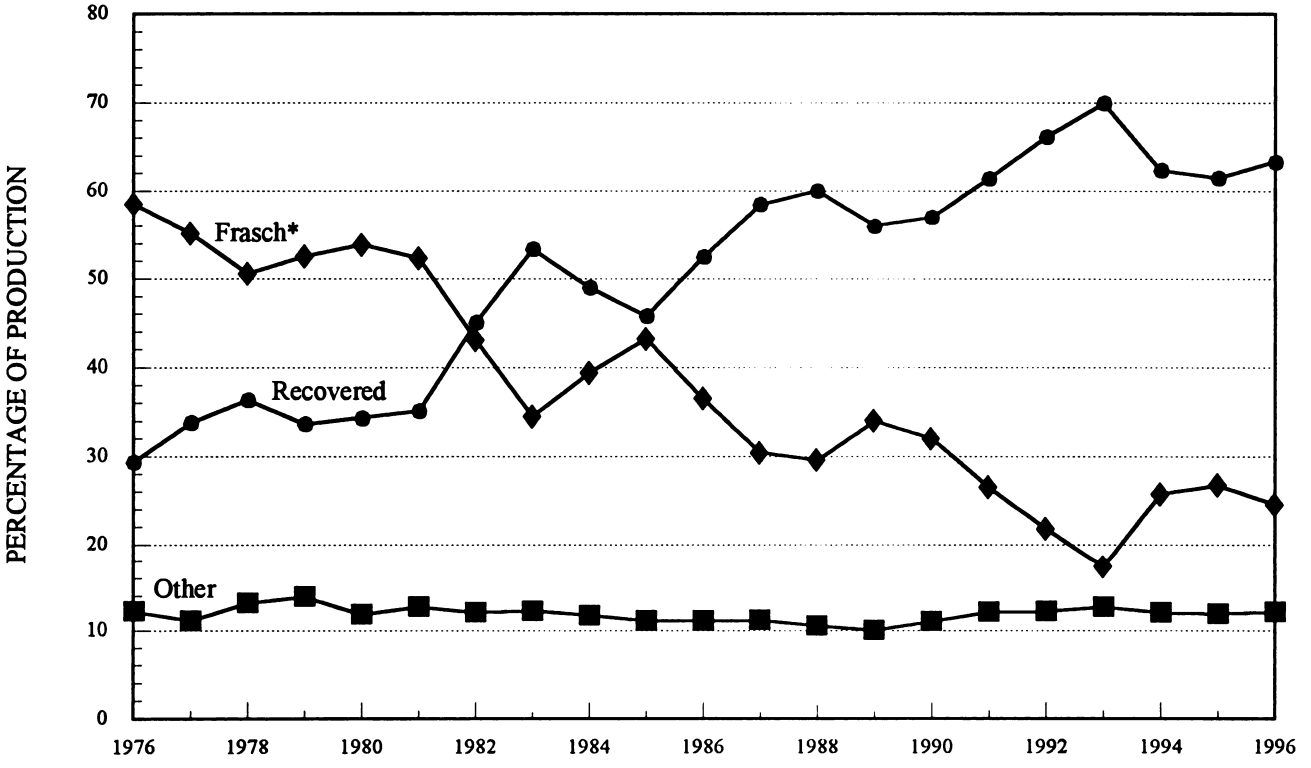
FIGURE 2

TRENDS IN THE PRODUCTION OF SULFUR IN THE UNITED STATES





*Includes 10 months of Frasch data for 1993; the other 2 months are included with recovered sulfur data to conform with proprietary data requirements. Data for 1994-96 are estimates.

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TALC AND PYROPHYLLITE

By Robert L. Virta

The mineral talc is a hydrous magnesium silicate. A massive talcose rock is called steatite and an impure massive variety is referred to as soapstone. Talc is used commercially because of its softness, purity, fragrance retention, whiteness, luster, moisture content, oil and grease adsorption, chemical inertness, low electrical conductivity, high dielectric strength, and high thermal conductivity. Major markets for talc are ceramics, paint, paper, and plastics.

Pyrophyllite is a hydrous aluminum silicate with a structure similar to talc. Properties such as chemical inertness, high melting point, low electrical conductivity, and high dielectric strength make pyrophyllite useful for ceramic and refractory applications.

Legislation and Government Programs

The Department of Defense authorized the disposal of 974 metric tons of block and lump talc and 988 tons of ground talc from the National Defense Stockpile.

Production

Talc.—Ten companies operating 13 mines in 7 States produced talc, soapstone, and steatite. All operations were open pit mines except for two. The producers, listed in decreasing order of production, were Luzenac America Inc., Barrett's Minerals Inc., Gouverneur Talc Co., Dal Minerals Co., Milwhite Inc., United Clays of Texas, Suzorite Mineral Products Inc., Richmark Resources Ltd., New Alberene Stone Co., and Steatite of Southern Oregon. Luzenac America, Barrett's Minerals, Gouverneur Talc, and Dal Minerals were the largest domestic producers, accounting for over 70% of the market.

U.S. mine production was 994,000 tons valued at $31.1 million in 1996, down from 1,060,000 tons in 1995. *(See tables 1 and 2.)* Production increased in Montana and Virginia and decreased in California, New York, Texas, and Vermont. Montana led all States in the tonnage and value of talc produced, followed by Texas, Vermont, New York, California, Virginia, and Oregon in decreasing order of production. Mines that operated in Montana, New York, Texas, and Vermont accounted for nearly all of the domestic talc production.

Domestic production data for talc were developed by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. mines. Survey forms were sent to 10 companies. All companies responded to the survey.

Pyrophyllite.—Pyrophyllite was mined by two companies operating three mines in North Carolina and one company operating one mine in California. Piedmont Minerals Co. Inc. and Standard Mineral Co. Inc. operated in North Carolina and Standard Industrial Minerals Inc. mined pyrophyllite in California. Production of pyrophyllite increased slightly from that of 1995. North Carolina accounted for most of the domestic pyrophyllite production.

Domestic production for pyrophyllite was developed by the USGS from a voluntary survey of U.S. mines. Survey forms were sent to three companies. All companies responded to the survey.

Consumption

Talc.—Slightly more than 909,000 tons of talc valued at $100 million was sold or used in 1996, up from 901,000 in 1995. Sales or use of talc increased in Alabama, Montana, Texas, and Virginia and decreased in California, New York, and Vermont. Of the 909,000 tons of talc sold or used, 791,000 tons reportedly was sold for domestic use and approximately 118,000 tons was exported.

Domestic markets include ceramics (pottery, sanitaryware, tiles, etc.), paper, paint, plastics, roofing, cosmetics, insecticides, rubber, and refractories, in decreasing order of consumption. *(See table 3.)* Domestic sales to the paint, paper, plastic, and refractories increased in 1996. The largest increase was for the paper market, where reported sales increased from 139,000 tons in 1995 to 180,000 tons in 1996. Some of the increase was attributed to the growing pitch control market for primary and secondary (recycled) paper production. However, an estimated 35,000 tons reported under domestic paper sales was exported to Canadian paper mills rather than used domestically. Domestic sales to the paper industry are estimated to be 145,000 tons rather than 180,000 tons. Sales to the plastics markets also increased, corresponding to an increased use of talc as a filler and extender in plastic products. Increases in other markets were relatively minor.

Approximately 83,600 tons of talc were reported under the "Other" category by respondents. Of this amount, 8,310 tons were used in asphalt and automobile body filler applications, 70 tons for sculpture media, and 74,000 tons were used in caulks, joint compounds, paint and putties, vinyl sheet flooring, and tile flooring. The remainder of the "Other" category (1,220 tons) was used in applications that were not identified by respondents. More than 99% of the data presented in table 3 was reported by the companies; the remainder was estimated from reported prior-year data adjusted according to industry trends.

Most of the imported talc was not included in the domestic end-use data shown in table 3. Approximately two-thirds of the imported talc was purchased primarily by mineral brokers who

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do not participate in the USGS canvass. An estimate of the end-use breakdown based on countries of origin, ports of entry, importing companies, and regional end-use patterns is ceramics-refractories, 9,000 tons; cosmetics, 8,000 tons; paint, 10,000 tons; paper, 4,000 tons; plastics, 44,000 tons; rubber, 8,000 tons; and unknown 15,000 tons.

Pyrophyllite.—Domestic consumption of pyrophyllite increased 5% from that of 1995. Sales in California and North Carolina increased in 1996. Pyrophyllite was used in ceramics, refractories, paint, insecticides, plastics, and rubber applications in decreasing order of consumption. Sales increased for ceramic, insecticide, and paint applications, decreased for plastic and refractory applications, and remained unchanged for rubber applications. The largest increase in consumption was for ceramics uses. Ceramic and refractory uses accounted for over 70% of the pyrophyllite sales.

Domestic consumption data for talc and pyrophyllite were developed by the USGS from a voluntary survey of U.S. mills. Survey forms were sent to 10 companies operating 18 mills in 11 States for talc and 3 companies operating 3 mills in 2 States for pyrophyllite. All companies responded to the survey.

Prices

Talc prices varied depending on the quality and on the degree and method of processing. The unit value of crude talc was estimated to be $31 per ton. Over 50% of the crude ore value included in table 1 was estimated because most producers do not sell crude talc and could not provide a crude ore value. The average reported unit value of processed talc was $111 per ton. The average unit value of crude and processed pyrophyllite was essentially unchanged from that of 1995.

Unit values for imported crude and ground talc ranged from $7 per ton to $585 per ton for shipments exceeding 100 tons. Unit values for cut or sawed talc ranged from $517 per ton to $1,241 per ton for shipments exceeding 100 tons. The average unit value for all shipments, including those of 100 tons or less, was $60 per ton for crude talc; $100 per ton for ground talc; and $997 per ton for cut or sawed talc. The average unit value for imported crude talc decreased 30% because of increased imports of lower valued talc from Australia and China in 1996. Imports of Australian crude talc increased from 10,300 tons to 21,700 tons with the value decreasing from $78 per ton to $63 per ton. Imports of Chinese crude talc increased from 48,700 tons to 75,400 tons with the value decreasing from $79 per ton to $59 per ton. The average unit value for ground talc increased 16%. In general, the values of larger tonnage shipments were unchanged from those of 1995. There were, however, more small shipments (1 to 10 tons) of talc whose unit value exceeded $500 per ton in 1996 than in 1995. A few shipments were extremely high, exceeding $2,000 per ton. These were likely to have been shipments of finished products such as talcum powder, sculpture-grade material, or possibly surface-treated talc. The average unit value for all imported talc was $110 per ton.

Unit values for exports of unground talc ranged from $80 per ton to $212 per ton for shipments exceeding 100 tons. The average value was $183 per ton. Unit values for exports of ground talc ranged from $48 per ton to $599 per ton with an average of $199 per ton. The average unit value for all exported talc was $197 per ton for all exports. The unit values for the crude talc decreased because fewer low tonnage-high value (exceeding $600 per ton) shipments were reported in 1996. The unit value for ground talc exports decreased 2%. As with imports, some of the high value talc exports probably were finished products such as talcum powder and sculpture-grade material.

Approximate equivalents, in dollars per metric ton, of price ranges for talc ranged from $92 to $450 per ton (Industrial Minerals, 1996). *(See table 4.)* Quoted prices should be used only as a guideline because they depend on the terms of the contract between seller and buyer.

Foreign Trade

Talc exports increased 5% in tonnage to 192,000 tons and 2% in value to $37.9 million. Canada was the largest importer of U.S. talc, followed by Mexico, Singapore (18,500 tons), Brazil (10,000 tons), Venezuela (9,070 tons), Japan, Belgium, and the Republic of Korea (7,350 tons). *(See table 5.)* Since 1990, data reported by domestic producers concerning exports to Mexico gradually has diverged from the Bureau of the Census data. Based on industry data, exports to Mexico are estimated to be two to three times those reported by the Bureau of the Census.

Talc imports increased 28% in tonnage to 187,000 tons and increased 39% in value to $20.5 million. Canada, China, and Japan supplied 74% of all talc imports. *(See table 6.)* Most of the talc imported from Japan was likely to have been either transshipments from other Southeast Asian countries or Australia or processed in Japan and reexported.

Imports listed by tonnage, source, and port district are: 87,600 tons from China through New Orleans-Baton Rouge, LA; 23,800 tons (mainly from Japan and France) through New York-New Jersey; 14,000 tons from Australia and China through Houston, TX; 13,800 tons (mainly from Japan) through Los Angeles, CA; 11,500 tons (mainly from Canada) through Buffalo, NY; 10,300 tons (mainly from Canada) through Detroit, MI; 8,800 tons (mainly from China and Hong Kong) through Brownsville, TX; and 5,280 tons (mainly from Australia) through Mobile, AL. The remaining imports were scattered among the many other port districts.

The large tonnages of talc imported in recent years appear to conflict with historical and industry trends. Most talc markets have been relatively stable with minor fluctuations corresponding to the domestic economy. The exception is the plastics market, which has grown at a faster pace. With domestic producers reporting declining sales to the plastics industry, it appears that the industry has turned to imported talc to meet those increased demands. Despite this, it does not appear that the domestic markets have expanded sufficiently to accommodate an increase from 48,000 tons in 1987 to 187,000

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tons in 1996, particularly considering that exports and sales by domestic producers have not declined significantly during that same period. It is likely that the imports reported by the U.S. Bureau of the Census contain other materials in addition to talc. Domestic talc producers are estimated to have imported between 20,000 and 30,000 tons in 1996. It is estimated that brokers, toll grinders, etc. imported an additional 60,000 to 70,000 tons for domestic use, based on Bureau of the Census and Journal of Commerce Port Import/Export Reporting Service data. A small amount (perhaps 5,000 to 7,000 tons) of the talc imports probably was reexported without entering U.S. markets.

World Review

China remained the world's leading producer of talc, followed by the United States, India, Finland, and Brazil in decreasing order of production. Japan was the largest producer of pyrophyllite, followed by the Republic of Korea, Brazil, and India. China, Japan, the Republic of Korea, and the United States produced 72% of the world's talc and pyrophyllite. *(See table 7.)*

Outlook

The past 10 years have been a period of change for the talc industry. The major talc producers pulled out of California, many small companies withdrew from the talc market, and several large talc producers were purchased by a single corporation and then sold to a foreign company. During this time, domestic production has declined slightly while consumption levels have been maintained. Exports decreased in the early 1990's but have rebounded since then. Imports have risen during this time but appear to be filling new markets or meeting the demands of expanding markets rather than displacing domestic talc from most markets.

Demand for domestic talc should continue at its current pace. Talc imports are expected to continue to increase gradually. Ceramics will continue to be the major domestic end use for talc, while plastics should offer the greatest potential for growth. The pyrophyllite industry has been stable for many years and this trend is expected to continue. Major domestic end-use markets will continue to be in ceramics and refractories.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT TALC AND PYROPHYLLITE STATISTICS 1/

(Thousand metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Mine production, crude:						
Talc		997	968	935	1,060	994
Pyrophyllite		W	W	W	W	W
Total		997	968	935	1,060	994
Value:						
Talc	thousands	$31,300	$27,800	$30,400	$31,700	$31,100
Pyrophyllite	do.	W	W	W	W	W
Total	do.	$31,300	$27,800	$30,400	$31,700	$31,100
Sold by producers, crude and processed:						
Talc		817	900	923	901	909
Pyrophyllite		W	W	W	W	W
Total		817	900	923	901	909
Value:						
Talc	thousands	$94,700	$104,000	$116,000	$99,900	$100,000
Pyrophyllite	do.	W	W	W	W	W
Total	do.	$94,700	$104,000	$116,000	$99,900	$100,000
Exports 2/ (talc)		175	135	154	183	192
Value	thousands	$30,100	$27,200	$29,800	$37,100	$37,900
Imports for consumption		80	100	155	146	187
Value	thousands	$12,400	$10,800	$14,900	$14,800	$20,500
Apparent consumption 3/		902	933	936	1,020	989
World: Production		8,490 r/	8,410 r/	8,090 r/	8,400 r/	8,190 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes powders--talcum (in package), face, and compact.

3/ Production, plus imports, minus exports, plus adjustments in Government and industry stock. Does not include pyrophyllite.

TABLE 2
CRUDE TALC PRODUCED IN THE UNITED STATES, BY STATE 1/ 2/

(Thousand metric tons and thousand dollars)

	1995		1996	
State	Quantity	Value	Quantity	Value
Oregon	W	W	(3/)	84
Texas	294	5,840	225	5,100
Other 4/	765	25,800	769	25,900
Total	1,060	31,700	994	31,100

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes pyrophyllite.

3/ Less than 1/2 unit.

4/ Includes California, Montana, New York, Oregon (1995), Vermont, and Virginia (1996).

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TABLE 3
END USES FOR GROUND TALC 1/ 2/

(Thousand metric tons)

Country	1995	1996
Ceramics	270	267
Cosmetics	23	19
Insecticides	7	7
Paint	146	148
Paper	139	180
Plastics	33	42
Refractories	--	1
Roofing	43	39
Rubber	18	3
Other 3/	94	84
Total	772	791

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes pyrophyllite.
3/ Includes art sculpture, asphalt filler, auto body filler, construction caulks, joint compounds, flooring, and other uses not specified.

TABLE 4
PRICE OF TALC

(U.S. dollars per metric ton)

New York:	
Paint:	
200 mesh	110
400 mesh	198
Ceramic:	
200 mesh	91
325 mesh	101
Italian, cosmetic-grade	263
Chinese, normal (ex-store):	
UK 200 mesh	285-323
UK 350 mesh	300-330

Sources: Industrial Minerals (London), Dec. 1996.

TABLE 5
U.S. EXPORTS OF TALC 1/ 2/

(Thousand metric tons and thousand dollars)

	1995		1996	
Country	Quantity	Value	Quantity	Value
Belgium	2	323	8	1,680
Canada 3/	61	10,800	65	12,200
Japan	10	1,600	8	1,280
Mexico	11	1,600	27	3,300
Other 4/	99	22,800	84	19,400
Total	183	37,100	192	37,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Excludes powder--talcum (in package), face, and compact.
3/ Probably includes shipments in transit through Canadian ports.
4/ Includes 70 countries in 1995 and 62 countries in 1996.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF TALC, BY COUNTRY 1/

Country	Not crushed or powdered		Crushed or powdered		Cut and sawed		Total unmanufactured	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
1995:								
Brazil	--	--	80	$25	324	$271	404	$296
Canada	137	$27	25,400	4,750	499	375	26,000	5,150
China	48,700	3,850	2,130	289	643	363	51,500	4,500
France	6,020	595	6,530	328	602	584	13,100	1,510
Japan	--	--	42,100	792	55	14	42,200	807
Other 2/	10,900	1,160	879	258	509	1,160	12,300	2,580
Total	65,800	5,630	77,100	6,440	2,630	2,770	146,000	14,800
1996:								
Brazil	--	--	76	17	427	371	503	387
Canada	197	41	25,400	5,170	406	322	26,000	5,530
China	75,400	4,460	7,580	572	782	438	83,800	5,480
France	42	37	6,470	352	4,870	4,850	11,400	5,240
Japan	1	2	28,800	571	1	3	28,800	575
Other 2/	34,000	2,030	1,700	322	475	951	36,200	3,300
Total	110,000	6,570	70,100	7,000	6,960	6,930	187,000	20,500

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes 24 countries in 1995 and 27 countries in 1996.

Source: Bureau of the Census.

TABLE 7
TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Argentina:					
Steatite	425	840	500 e/	300 r/ e/	300
Talc	21,155	17,244	17,350 r/	17,300 e/	17,000
Australia: e/					
Pyrophyllite	5,000	5,000	5,000	5,000	5,000
Talc	210,000	210,000	210,000	210,000	210,000
Austria: Steatite	145,664	136,640	130,602	131,614 r/	130,000
Brazil:					
Pyrophyllite	144,000 r/	160,000 r/	148,000 r/	150,000 r/	150,000
Talc	286,000 r/	320,000 r/	360,000 r/	360,000 r/	360,000
Canada: Pyrophyllite, soapstone, talc	104,000 e/	108,000 e/	130,000	116,000	75,000 p/
Chile: Talc	1,493	5,058	5,351	5,000 e/	5,000
China: Unspecified e/	2,650,000	2,700,000	2,400,000	2,400,000	2,400,000
Colombia: Pyrophyllite, soapstone, talc	13,340	19,550	18,000	19,248 r/	20,000
Egypt: Pyrophyllite, soapstone, steatite, talc	8,319	4,746	4,125	4,000 e/	4,000
Eritrea: Talc 4/	XX	XX	3	--	--
Finland: Talc	371,000	399,000	453,000	450,000 e/	400,000
France: Talc	350,500 r/	299,900 r/	306,300	322,300 r/	300,000
Germany: Talc (marketable)	23,509	21,152	11,583	12,000 e/	12,000
Greece: Steatite e/	700	700	500	500	500
Hungary: Talc e/	10,000	10,000	10,000	10,000	10,000
India:					
Pyrophyllite	79,197	82,269	85,335 r/	131,137 r/	130,000
Steatite	368,003	385,121	398,006 r/	439,509 r/	450,000
Iran: Talc 5/	23,707	18,000	27,000 r/ e/	25,000 r/ e/	25,000
Italy: Steatite and talc e/	183,530 6/	142,000	139,000	130,000	130,000
Japan:					
Pyrophyllite	1,055,897	1,028,399	934,007	947,713 r/	911,700
Talc	61,120	57,229	56,120	57,269 r/	53,700
Korea, North: Unspecified e/	170,000	180,000	180,000	180,000	180,000
Korea, Republic of:					
Pyrophyllite	602,580	644,890	707,951	789,994 r/	790,000
Talc	149,862	53,923	35,340	29,364 r/	30,000

See footnotes at end of table.

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TABLE 7--Continued
TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons)

Country 3/	1992	1993	1994	1995	1996 e/
Macedonia: Talc e/	15,000	10,000	10,000	10,000	10,000
Mexico: Talc	19,559	14,400	14,900 r/	15,443 r/	16,000
Nepal: Talc 7/	3,820	1,340	1,500 e/	1,500 e/	1,500
Norway: Talc e/	60,000	50,000	28,000 r/	30,000 r/	30,000
Pakistan: Pyrophyllite	23,676	46,846	37,151 r/	35,043 r/	35,000
Paraguay: Unspecified e/	200	200	200	200	200
Peru: e/					
Pyrophyllite	8,000	8,000	8,000	8,000	8,000
Talc	2,000	1,200	1,200	1,200	1,200
Portugal: Talc	9,166	9,349	8,367 r/	8,400 r/ e/	8,400
Romania: Talc	6,330	9,000	8,952	9,976	10,000
Russia: Talc e/ 8/	150,000	131,688 6/	100,000	100,000	100,000
South Africa					
Pyrophyllite	3,053	4,287	5,507	5,519 r/	5,500
Talc	13,882	8,798	8,202	9,173 r/	9,000
Spain: Steatite e/	70,000	65,000	65,000	65,000	65,000
Sweden: Talc e/	10,000	--	--	--	--
Taiwan: Talc	6,085	5,015	4,290	4,000 e/	4,000
Thailand:					
Pyrophyllite	34,638	43,404	55,326	76,189 r/	75,000
Talc	4,786	7,007	8,950	4,252 r/	4,000
Turkey e/	3,918 6/	4,000	4,000	4,000	4,000
United Kingdom: Talc, soapstone, pyrophyllite	5,216	5,317	5,275 r/	5,000	4,000
United States:					
Pyrophyllite	W	W	W	W	W
Talc	997,000	968,000	935,000	1,060,000	994,000 6/
Uruguay: Talc, soapstone, pyrophyllite e/	1,500	1,500	1,500	1,000	1,000
Zambia: Talc	366	62	76	70 e/	70
Zimbabwe: Talc	2,203	1,349	2,049	2,080 r/	2,100
Grand total	8,490,000 r/	8,410,000 r/	8,090,000 r/	8,400,000 r/	8,190,000
Of which:					
Pyrophyllite	1,960,000 r/	2,020,000 r/	1,990,000 r/	2,150,000 r/	2,110,000
Steatite	585,000	588,000	595,000 r/	637,000 r/	646,000
Talc	2,810,000 r/	2,630,000 r/	2,620,000 r/	2,750,000 r/	2,610,000
Unspecified	3,140,000	3,170,000	2,880,000	2,860,000	2,820,000

e/ Estimated. p/ Preliminary. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 12, 1997.

3/ In addition to the countries listed, the former Czechoslovakia produces talc, but information is inadequate to make reliable estimates of output levels.

4/ Eritrea became independent from Ethiopia in May 1993; however, information is inadequate to formulate reliable estimates prior to 1994.

5/ Data based on Iranian fiscal year beginning Mar. 21 of year stated.

6/ Reported figure.

7/ Data based on Nepalese fiscal year beginning mid-July of year stated.

8/ U.S.S.R. dissolved in Dec. 1991; however, information is inadequate to formulate reliable estimates for individual countries, except Russia.

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THORIUM

By James B. Hedrick

Thorium is a soft, very ductile, silver-gray, heavy, metallic element of the actinide series of elements. It is represented by the chemical symbol Th or the isotopic symbol Th^{232}. Thorium metal has a very high melting point, while the oxide, which is also called thoria, has the highest melting point of all the oxides. Twelve isotopes of thorium are known with atomic masses from 223 to 234. Th^{232} emits radioactive alpha particles and has a very long half-life of 1.41×10^{10} years. Daughter products of thorium's disintegration produce alpha, beta, and gamma emissions; however, most have relatively short half-lives.

Thorium was discovered in 1828 by Swedish chemist and mineralogist Jons Jakob Berzelius. He named it thoria, after Thor, the ancient Norse god of thunder. Berzelius isolated the element from a black silicate mineral from the island of Lövö near Brevig, Norway. Subsequently, the black mineral from which thoria was derived was named thorite. Thorium's radioactivity was discovered independently in 1898 by Madame Curie and C. G. Schmidt.

Thorium is the 39th most abundant of the 78 common elements in the Earth's crust, at 7.2 parts per million. It is about three times more abundant than uranium and is associated with uranium in igneous rocks. In sedimentary rock, thorium and uranium contents are more distinct, as the primary thorium minerals are typically more resistant to geochemical and physical weathering. Thorium occurs in several minerals, the most common being monazite and thorite.

Domestic consumption of refined thorium products decreased in 1996, according to the U.S. Geological Survey (USGS). The value of thorium metal and compounds used by the domestic industry was estimated to be about $300,000. Thorium production was primarily from the rare-earth-thorium-phosphate mineral, monazite, a byproduct of processing heavy-mineral sands for titanium and zirconium minerals or tin minerals. Thorium compounds were produced from monazite during processing for the rare earths. Only a small portion of the thorium produced was consumed; most was discarded as waste. The major monazite-producing countries were Brazil, China, India, Malaysia, and Sri Lanka. Essentially all of the thorium compounds, metal, and alloys used by the domestic industry were derived from imports, company stocks, or material sold from U.S. Government stocks.

Limited demand for thorium, relative to the rare earths, continued to create an extensive world oversupply of thorium compounds and residues. Most major rare-earth processors have switched feed materials to thorium-free intermediate compounds. Excess thorium, not designated for commercial use, was either disposed of as a radioactive waste or stored for potential use as a nuclear fuel or other application. Principal nonenergy uses have shifted from refractory applications to welding electrodes and lighting.

Problems associated with thorium's natural radioactivity represented a significant cost to those companies involved in its mining, processing, manufacture, and use. Increased costs to comply with environmental regulations, potential legal liabilities, and the costs to purchase storage and waste disposal space were the principal deterrents to its commercial use. According to industry sources, health concerns associated with thorium's natural radioactivity have not been a significant factor in switching to alternative nonradioactive materials.

Legislation and Government Programs

The calendar year 1996 included parts of the U.S. Government fiscal years 1996 and 1997. Public Law 104-106, the National Defense Authorization Act for fiscal year 1996, was not enacted until February 10, 1996, because of significant delays in the Congressional budget process and a Presidential veto. It did not change the previous authorization for disposal of all stocks of thorium nitrate in excess of the National Defense Stockpile (NDS) goal of 272,155 kilograms (600,000 pounds). The National Defense Authorization Act for fiscal year 1997, Public Law 104-201, was enacted on September 23, 1996. It did not change previous authorizations for the disposal of 2,946,185 kilograms (6,495,225 pounds) of thorium nitrate classified as excess to goal.

Production

Domestic mine production data for thorium-bearing monazite were developed by the USGS from a voluntary survey of U.S. operations entitled, "Thorium." The one mine to which a survey form was sent responded. Thorium was not produced in 1996; however, the mine that had previously produced thorium-bearing monazite continued to operate and maintained capacity on standby.

RGC (USA) Minerals Inc., a wholly owned subsidiary of the Australia-based Renison Goldfields Consolidated Ltd., ceased monazite recovery at its dredging operation at Green Cove Springs, FL, in 1994. RGC (USA) discontinued byproduct recovery of monazite due to decreased demand for thorium-bearing rare-earth ores. Processing of titanium and zirconium minerals continued at the site.

Essentially all thorium alloys and compounds used by the domestic industry were derived from imports, company stocks, or materials sold from U.S. Government stockpiles. Domestic companies processed or fabricated various forms of thorium for nonenergy uses such as ceramics, incandescent lamp mantles, carbon arc lamps, magnesium-thorium alloys, refractories, and

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welding electrodes.

Consumption

Statistics on domestic thorium consumption are developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments. (*See table 1*).

Domestic thorium producers reported consumption of 4.9 metric tons of thorium oxide equivalent in 1996, a decrease of 10% from the revised 1995 level of 5.4 tons. Nonenergy uses accounted for essentially all of the total consumption. The approximate distribution of thorium by end use, on an equivalent oxide basis, based on data supplied by processors and several consumers, was as follows: welding electrodes, 65%; lighting, 20%; ceramics and refractories, 14%; nuclear applications, 1%.

Thorium oxide (thoria) has the highest melting point of all the metal oxides, 3,300 °C. This property contributed to its use in several refractory applications. High-temperature uses were in ceramic parts, investment molds, and crucibles.

Thorium nitrate was used in the manufacture of mantles for incandescent "camping" lanterns, including natural gas lamps and oil lamps. Thorium mantles provide an intense white light that is adjusted towards the yellow region by a small addition of cerium. Thoriated mantles were not produced domestically due to the development of a suitable thorium-free substitute.

Thorium nitrate also was used to produce thoriated tungsten welding electrodes. Thoriated tungsten welding electrodes were used to join stainless steels, nickel alloys, and other alloys requiring a continuous and stable arc to achieve precision welds.

The nitrate form was also used to produce thoriated tungsten elements used in the negative poles of magnetron tubes. Thorium was used because of its ability to emit electrons at relatively low temperatures when heated in a vacuum. Magnetron tubes were used to emit electrons at microwave frequencies to heat food in microwave ovens and in radar systems used to track aircraft and weather conditions.

Thorium was used in other types of electron emitting-tubes, elements in special use light bulbs, high-refractivity glass, radiation detectors, computer memory components, catalysts, photo conductive films, target materials for X-ray tubes, and fuel cell elements.

In metallurgical applications, thorium was alloyed primarily with magnesium. Thorium metal has a high meeting temperature of 1,750 °C and a boiling point of about 4,790 °C. Magnesium-thorium alloys used by the aerospace industry are lightweight and have high strength and excellent creep resistance at elevated temperatures. Thorium-free magnesium alloys with similar properties have been developed and are expected to replace most of the thorium-magnesium alloys presently used. Small quantities of thorium were used in dispersion-hardened alloys for high-strength, high-temperature applications.

Thorium was used as a nuclear fuel in the thorium-232/uranium-233 fuel cycle. No domestic commercial reactors are operating with this fuel cycle. The use of thorium as a nuclear fuel is not expected to grow due to the current availability of low-cost uranium.

Stocks

Government stocks of thorium nitrate in the NDS were 3,218,551 kilograms (7,095,691 pounds) on December 31, 1996. The NDS shipped 815 kilograms (1,796 pounds) for waste disposal research in 1996. No stocks of thorium nitrate were sold during the year.

The U.S. Department of Energy's (DOE) inventory at yearend was 672,000 kilograms of thorium oxide equivalent contained in ore, metal, and various compounds. The DOE contractor shipped an estimated 129,000 kilograms to waste disposal in 1996.

Prices

The price range of Australian monazite [minimum 55% rare-earth oxide including thoria, free-on-board (f.o.b.)/free into container depot (f.i.d.)], as quoted in Australian dollars (A$), remained unchanged at the previous years range of A$300-A$350 per ton. Changes in the United States-Australia foreign exchange rate in 1996, resulting from a weaker U.S. dollar on world markets, caused the U.S. dollar exchange rate to be down $0.07 against the Australian dollar at yearend. The U.S. price range, converted from Australian dollars, increased slightly to US$244-US$285[1] per ton at yearend 1996, compared with US$222-US$259[2] per ton at yearend 1995 (Metal Bulletin, 1995; 1996). Prices for monazite remained depressed as several principal world rare-earth processors continued to process only thorium-free feed materials.

Thorium oxide prices quoted by Rhône-Poulenc Basic Chemicals Co. were unchanged from yearend 1995, f.o.b., Shelton, CT, were 99.9% purity, $88.50 per kilogram; and 99.99% purity, $107.25 per kilogram.

Thorium prices quoted by Reade Manufacturing Co., a division of Magnesium Elektron, Lakehurst, NJ, at yearend 1996 were $330.69 per kilogram ($150.00 per pound) for thorium hardener (80% Mg-20% Th) in single drum quantities and $61.73 per kilogram ($28.00 per pound) for thorium-containing HZ-32 magnesium alloy ingot. The commercial magnesium-zinc-thorium alloy, ZH-62, was $47.91 per kilogram ($21.73 per pound). Thorium alloys were available

[1]Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of U.S. $1.00=A$1.2290 based on yearend foreign exchange rates (U.S. Department of the Treasury, Financial Management Service, Treasury Reporting Rates of Exchange as of December 31, 1996, [1997], p. 1.)

[2]Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of U.S. $1.00=A$1.3510 based on yearend foreign exchange rates (U.S. Department of the Treasury, Financial Management Service, Treasury Reporting Rates of Exchange as of December 31, 1995, [1996], p. 1.)

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only from Magnesium Elektron stocks in Manchester, England.

World Review

Thorium demand remained depressed as industrial consumers expressed concerns with the potential liabilities, the costs of complying with environmental monitoring and regulations, and cost increases at approved waste disposal sites.

Outlook

Nonenergy uses for thorium in the United States have decreased substantially over the past seven years. Domestic demand is forecast to remain at current depressed levels unless low-cost technology is developed to dispose of residues. Manufacturers have successfully developed acceptable substitutes for thorium-containing incandescent lamp mantles, paint and coating evaporation materials, magnesium alloys, ceramics, and investment molds. The traditionally small markets for thorium compounds, welding electrodes, and lighting, are expected to remain the leading consumers of thorium compounds through the end of the millennium. Thorium's potential for growth in nonenergy applications is limited by its natural radioactivity. Its greatest potential exists in energy applications, as a nuclear fuel or subatomic fuel, in an industry that accepts radioactivity. In the long term, high disposal costs, increasing regulations, and public concerns related to thorium's natural radioactivity are expected to continue to depress its future use.

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TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS 1/

(Kilograms of thorium dioxide, unless otherwise specified)

	1992	1993	1994	1995	1996
Exports: Compounds	93	189	7	75	58
Imports:					
Thorium ore metal, excluding monazite	187,000	--	--	--	--
Compounds	13,500	18,300	3,150	20,500	26,400
Shipments from Government stockpile excesses	--	--	--	--	--
Consumption, reported nonenergy applications 2/	35,400 r/	8,260 r/	3,590 r/	5,390 r/	4,920
Prices, yearend, dollars per kilogram:					
Nitrate	$21.36 3/	$22.25 3/	$23.30 3/	$23.30 3/	$14.32 4/
Oxide	$63.80 3/	$65.00 3/	$63.80 3/	NA	$64.45 4/

r/ Revised. NA Not available.

1/ Data are rounded to three significant digits.

2/ All domestically consumed thorium was derived from imported metals, alloys, and compounds; monazite containing thorium has been imported but has not recently been used to produce thorium products.

3/ Source: Rhône-Poulenc Basic Chemicals Co.

4/ Source: Bureau of the Census, average import price.

TABLE 2
U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS 1/

(Kilograms, unless otherwise specified)

	1995		1996		Principal destinations,
	Quantity	Value	Quantity	Value	sources, and quantities, 1996
Exports:					
Thorium ore, monazite concentrate	--	--	2,000	$3,360	United Kingdom 2,000.
Compounds	75	$25,300	58	14,400	Germany 50; Canada 8.
Imports:					
Thorium ore, monazite concentrate	40	10,500	101	41,000	Australia 81; France 20.
Compounds	20,500	942,000	26,400	1,440,000	France 26,300; Switzerland 16.

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

TABLE 3
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1992	1993	1994	1995	1996 e/
Australia e/	6,000	3,000	--	--	--
Brazil e/	1,400 4/	1,400	1,400	1,400	1,400
China e/	1,800	1,800	1,800	1,800	1,800
India e/	4,000	4,600	4,600	5,000	5,000
Malaysia	777	407	425	814	450
South Africa e/ 5/	430	430	131	--	--
Sri Lanka e/	200	200	200	200	200
Thailand	89	220	57	60	--
United States	W	W	W	--	--
Zaire e/	50	20	20	20 r/	10
Total	14,700	12,100	8,630	9,230 r/	8,860

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

1/ Table includes data available through May 28, 1997.

2/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

3/ In addition to the countries listed, Indonesia, North Korea, the Republic of Korea, Nigeria, and the former U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

4/ Reported figure.

5/ Monazite occurs in association with titanium sands mining but is not necessarily recovered.

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TIN

By James F. Carlin, Jr.

In 1996, there was no domestic mine production of tin. Of the primary tin used domestically, 25 firms consumed about 84%. The major uses were as follows: cans and containers, 25%; electrical, 20%; transportation, 12%; construction, 10%; and other, 33%. The estimated value of primary metal consumed domestically was about $330 million.

About 11,000 metric tons of tin in purchased old and new tin scrap, including tin alloys, was recycled. Of this, about 7,600 tons was old scrap. About one-fifth of the tin consumed in the United States was produced from scrap at 7 detinning plants and 110 secondary nonferrous metal-processing plants. There was continued interest in the recycling of used tin cans, largely owing to the rising costs and limited space of landfills. The recycling rate for steel cans was 58% in 1996, having risen from 56% in 1995, 53% in 1994, 40% in 1993, and 15% in 1988. By yearend, 11,765 tons of pig tin had been sold from the National Defense Stockpile (NDS), leaving 112,954 tons in inventory, all of which was considered to be in excess.

World tin mine output increased only slightly. Industry observers believed that after 14 consecutive years of an excess of tin in world markets, supply and demand moved into an approximate equilibrium. The average Platt's Metals Week composite price of tin declined very slightly.

Tin was mined in 23 countries, the top 5 of which accounted for about 82% of the world total of 196,000 tons. China was the largest producer (31% of the world total), and was followed by Indonesia (20%), Peru (14%), Brazil (10%), and Bolivia (8%).

World tin reserves were estimated to be 7 million tons and were considered to be adequate to meet the world's future tin requirements. Assuming that the world primary tin consumption will be 200,000 tons annually, these reserves would last 35 years. Most tin reserves were in Asia and South America.

Legislation and Government Programs

The NDS continued in its seventh year of being managed by the U.S. Department of Defense, with day-to-day operations being guided by the Defense Logistics Agency (DLA). In 1996, the DLA sold 11,765 tons of pig tin from the stockpile. Of this total, 5,000 tons represented a long-term sales contract to Considar Corp. (New York, NY). From January to September, the DLA continued its daily tin sales program under the same format as in the prior year—sales held each day, with orders for lots of 5 tons or more being accepted daily between 1:30 p.m. and 3:30 p.m. at the price set by the DLA for that day. Then, at the beginning of fiscal year 1997 (starting October 1, 1996), the daily tin sales program was changed to a monthly spot sales program for which 2,000 tons of tin was allocated. Another 10,000 tons of material was to be sold under two long-term contracts—one in February 1997 and one in August 1997.

The following depots held the largest inventories of tin, in descending order: Hammond, IN, Point Pleasant, WV, Anniston, AL, and Stockton, CA. At yearend, 112,954 tons of tin was in the NDS.

Production

Mine Production.—There was no domestic tin mine production in 1996. This was the third consecutive year there had been no domestic tin mine production, after many years of having one or two small tin mines operating.

Secondary Production.—The United States is believed by industry observers to be the world's largest producer of secondary tin. Tin metal recovered from new tinplate scrap and used tin cans was the only type of secondary tin available in the marketplace as free tin; most secondary tin was produced from the various scrapped alloys of tin and recycled in those same alloy industries. Secondary tin from recycled fabricated parts was used in many kinds of products and was a major source of material, particularly for the solder and the brass and bronze industries.

The former Steel Can Recycling Institute, which had been started in 1988 and funded by five domestic tinplate producers to advance the collection, preparation, and transportation of steel can scrap, was in its third full year of expanded activities under its new name, the Steel Recycling Institute (SRI). The SRI fostered the collection of all steel scrap (ranging from appliances to cars), not just steel cans. The SRI continued to maintain a program of having representatives in various regions of the United States work with municipalities, scrap dealers, and detinners to promote the recycling of tin cans. The SRI announced that the recycling rate for steel cans reached a new high of 58% in 1996. In the 8 years of SRI's existence, the recycling rate for steel cans has nearly quadrupled—from 15% in 1988 to 58% in 1996. The SRI continued to be an active sponsor of the recycling of aerosol steel cans.

One of the major domestic detinners, Proler International Corp. (Houston, TX) was purchased by Schnitzer Steel Industries Corp. (Portland, OR). Proler had detinning operations in Coolidge, AZ, and Seattle, WA. Schnitzer, long a major operator of various West Coast scrap operations, announced that it planned to keep Proler's detinning plants intact (Metal Bulletin, 1996e).

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Consumption

Domestic consumption of primary tin increased by about 3.7% in 1996, whereas consumption of secondary tin fell by 24%, owing principally to less use in solder.

Tinplated steel and tin-free steel accounted for 24% of the 135 billion metal cans shipped domestically; aluminum accounted for 76%. These percentages were the same as those of 1995, when 134 billion cans were shipped domestically. Aluminum held virtually 100% of the beverage can market, while steel dominated in the food can and the "general-line" can markets (Can Manufacturers Institute, 1996). One of the domestic tinplate producers, Wheeling-Pittsburgh Steel Corp. (Wheeling, WV), announced the completion of construction of its new joint-venture tinplate mill in Belmont County, OH. The tin mill, known as Ohio Coatings Co., is a joint-venture with Dong Yang Tinplate Industries Co. Ltd. (Republic of Korea) and Nittetsu Shoji Inc. (Los Angeles, CA). The mill, which reportedly cost $80 million, is the first tinplating facility constructed in the United States since the early 1960's and replaces Wheeling's existing 50-year-old tin mill in Yorkville, OH. The State of Ohio assisted in the venture by obtaining a 10-year tax abatement for the mill and working with the county in seeking government grants for equipment and employee training. Capacity of the new facility is rated at 230,000 tons per year, which is slightly higher than that of the Yorkville plant. The mill was expected to use about 500 tons of tin per year. The plant will initially produce tinplate, and then later, tin-free steel. Wheeling-Pittsburgh is expected to supply from 75% to 80% of the light-gauge cold-rolled coil feedstock. Trial runs were initiated near yearend. The United Steelworkers Union struck Wheeling-Pittsburgh on October 1; the strike continued through the end of the year (CRU Tin Monitor, 1996b).

Prices

The Platt's Metals Week composite price for tin metal reached its peak for the year in April and ended the year somewhat lower than at the beginning of the year. The 1996 average annual composite price was slightly lower than that for 1995.

The London Metal Exchange (LME) remained the primary trading arena for tin. Tin was one of only six metals (along with aluminum, copper, lead, nickel, and zinc) to be traded on the LME. The Kuala Lumpur Commodities Exchange in Malaysia continued as an active tin trading forum.

Foreign Trade

Imports, which supply most domestic requirements, declined about 9% in 1996. Imports of tin in all forms (ore and concentrate, metal, waste, and scrap) remained free of U.S. duty. (*See tables 7, 8, and 9.*) In the United States, trading firms marketed most of the tin metal, which they imported from a variety of countries and warehoused in this country until they sold it to customers. Foreign-owned trading firms tended to dominate the field. Most tin dealers were based in the New York, NY, area. Some tin also was marketed directly in the United States by large foreign producers that maintained sales offices here and sold their tin metal, usually on a 1-year contract basis, only to the largest users. Perhaps foremost among these direct-sale operations was Indo-Metal Corp., which served as the exclusive North American sales outlet for tin metal produced by Indonesia's large tin producer, P.T. Tambang Timah.

For the fifth consecutive year, Brazil was the largest source of U.S. tin metal imports. Indonesia ranked second and was followed by Bolivia and China.

World Review

At the Association of Tin Producing Countries' (ATPC) 14th minister's conference in Singapore in September, it was announced that Australia and Thailand would be leaving the organization by yearend and that Brazil had decided to join in 1997. The Australian Government declared that its decision to leave the ATPC reflected its commitment to end mineral export controls. Thailand's decision to exit was reportedly a result of its declining tin output, which has caused the country to become a net tin importer (Platt's Metals Week, 1996).

Argentina.—U.S.-based Sunshine Mining and Refining Co. reported that it would be broadening its efforts to prove the viability of its Pirquitas silver-tin property in Argentina. The firm indicated that it would double its exploration expenditures to $2.8 million during 1996 and expected to make a development decision by early 1997. Pirquitas, only recently acquired by Sunshine, reportedly has a resource estimated to be 312 million ounces of silver and 463 million pounds of tin (Metal Bulletin, 1996c).

Brazil.—Three domestic metals companies—Paranapanema, its largest tin producer; Caraíba Metais, a copper producer; and Companhia Paraibuna Metais, a zinc producer—merged their operations into a new organization called Companhia Brasileira de Metais Nao Ferrosas. A number of pension funds also participated in the venture. The new combination reportedly had plans to invest $600 million, but the amount that could be directed to tin was unspecified. Paranapanema's tin production has declined in recent years, owing mostly to lower investment at the large Pitinga Mine in Amazonas State, where output could theoretically be as high as 30,000 tons per year of tin-in-concentrate; instead, Pitinga's actual 1996 production was estimated to be 15,000 tons. Paranapanema's other mines, including Massangana in Rondônia State, reportedly have only modest reserves. The company has a majority holding in Ebesa, which controls the garimpo activity in Rondônia. Production by the garimpo was estimated to be less than 15,000 tons per year in recent years (CRU Tin Monitor, 1996a).

Estanho do Rondônia, a joint venture formed in 1995 by two tin producers, reportedly was successfully merging the two operations. Cesbra, Brazil's second largest tin producer, and Best Metais e Soldas formed Estanho to move their smelting operations closer to the source of their tin ore, the Bom Futuro

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Mine, in western Rondônia State. Until the merger, Best had been producing about 850 tons of tin metal annually at its São Paulo smelter and exporting almost none. Cesbra had been producing about 1,600 tons of tin metal at two smelters in the States of Rio de Janeiro and Rondônia, and exporting about 600 tons per year. The two firms are now using their São Paulo and Rio de Janeiro smelters to make tin solders and fluxes. By consolidating all their tin smelting operations at Estanho do Rondônia's new smelter and at Cesbra's existing smelter in Rondônia, the two companies have brought extraction and smelting operations closer, thus reducing production costs. Estanho officials planned to export from 1,000 to 2,000 tons of tin per year, with most earmarked for the United States (American Metal Market, 1996c).

Arqueana de Minerios e Metais announced that it was conducting a feasibility study into the possible reopening of its tin-tantalum mine at Arqueana in Minas Gerais State. The firm had suspended production there in 1992 (Tin International, 1996b).

Paranapanema, the largest tin miner, announced plans to increase tin production, now 14,000 tons per year, to 20,000 tons per year. Reportedly, Paranapanema has developed a new tin processing method that cuts costs by 10%. One step involves agglomerating the cassiterite concentrate. Smelting would change from a three-stage fusion process to a two-stage process and eventually to a one-stage process. The company also considered moving its tin smelter to Pitinga, their largest mine site, 320 kilometers north of Manaus.

Canada.—Toronto-based Adex Mining Corp., announced the signing of an agreement with Malaysia Smelting Corp. (MSC) which enables MSC to control about 51% of Adex for an investment of $18 million. Under the agreement, Adex will use $1.5 million to complete a full-feasibility study of its 100%-owned Mount Pleasant property in New Brunswick. This could be completed by early 1997. After delivery of the feasibility study, the remaining money could be used to fund the reestablishment of mining operations at the Mount Pleasant property. MSC is interested in Adex's Mount Pleasant deposit as a long-term, stable source of tin concentrates. Plans called for operations to start possibly in late 1997. Mount Pleasant is a polymetallic deposit that is also the world's largest reserve of indium. At full production, product values as a percentage of cash flow are estimated to be 55% for tin, 30% for indium, 6% each for copper and zinc, and 3% for bismuth.

China.—Government officials complained that they could not control mining of tin by thousands of jobless farmers; consequently, China would likely exceed its export quota set by the ATPC. In 1994, China exported 44,000 tons of tin and unwrought alloys, more than double the 20,000 tons of annual exports it agreed to as a condition of joining the ATPC. In addition to accountable exports, a significant quantity of tin is smuggled out of China, according to Asian tin traders. Government officials claimed that as many as 300 million farmers no longer had work on the land because of the reforms that increased agricultural efficiency. Mining or construction work tends to be the first alternative choice for many of these displaced farmers. The Government found it difficult to organize and control these former farmers during this period of transition, while officials tried to develop alternative jobs in factories and elsewhere. The farmers searched for gold, tin, tungsten, and other minerals. Mining tin in China does not require a license and is done by farmers and local firms, as well as the two major companies based in Yunan Province and Guangxi Region that operate under the aegis of the Non-ferrous Metals Corp. The two firms together produce about 20,000 tons of tin per year. (Tin International, 1996c).

Two major European tinplate producers—Hoogovens (Holland) and Usinor (France)—announced that they would join forces to cooperate in a joint venture to construct and operate the first tin can manufacturing plant in China. The joint venture, to be based near Shanghai, will be formed by the Chinese steel company Baosteel (45%), the Shanghai-based distribution group Beiyi (30%), and the Belgian company Maison F. Mathieu (25%); a Usinor subsidiary is already present in China. The new plant, which will bear the name Shanghai Bao Yi Beverage Can Making Co. Ltd., was designed to produce 500 million cans per year. The project was to start in 1996, with production expected in early 1997. The Chinese market for two-piece beverage cans, which are now 100% aluminum, is estimated to be 5 billion units annually. Because the market is reportedly growing at an annual rate of 30% to 40% per year, it could quickly double to 10 billion cans per year. Hoogovens and Usinor will initially supply 20,000 tons of tinplate per year from their European tin mills (Metal Bulletin, 1996b).

Because of the strong increase in demand for domestic tinplate, three separate tinplate lines were under construction. At Yi Chang Steel, a 120,000- to 150,000-ton-per-year electrolytic tinning line was due to be commissioned late in 1996; Haikou Tinplate Co. was due to start up a new 100,000-ton-per-year plant on Hainan Island in mid-1997; and another line was being constructed in Fujian Province by a consortium that included Kawasaki Steel (Japan).

France.—Two large European packaging firms agreed to merge their metal packaging operations and sell 60% of the merged operation to a British investment firm. French-based Pechiney agreed to merge its food can, general line, and steel aerosol can businesses with Schmalbach Lubecca AG/Continental Can Europe, a subsidiary of Viag AG of Germany. By combining Pechiney's 19 production plants and Schmalbach's 16 production plants, a major European producer with annual sales of $1.4 billion was created. The second part of the merger was for British-based Doughty Hanson and Co. to acquire a 60% stake in the new organization, with Pechiney and Schmalbach each retaining a 20% interest. At the time of the merger, Schmalbach's metal packaging division had a work force of 4,700 people, and Pechiney's can operations employed 3,200 people (American Metal Market, 1996a).

Germany.—Rasselstein Hoesch GmbH, one of the world's major tinplate producers, announced a new investment program that would focus on the pickling mill and the continuous annealing line at its Andernach tin mill. The resultant capacity increase of 100,000 tons of tinplate would be primarily in the

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beverage can field. Rasselstein also planned to proceed with further down-gauging (thinner tinplate) as a means to compete with aluminum in the beverage can market. Tinplate accounted for 90% of the German beverage can market. Rasselstein planned to sell about 1.1 million tons of tinplate in 1996.

Industry reports indicated that Germany continues to lead Europe in the recycling of steel cans. According to figures from the Duales System Deutschland, 64% of tinplate packaging was recycled in Germany during the year. This compared favorably with a target of 49% and an aluminum recycling rate of 70%. The German target rate for tinplate for 1997 is 72%. The rest of Europe was not nearly so comprehensive in its recycling activities. The overall European Union recycling rate was reported to be 40%.

Indonesia.—P.T. Tambang Timah announced its intention to build an extra furnace at its Bangka Island tin smelter as part of a continuing expansion of the firm's production capacity. The new furnace would be the seventh at the smelter and would increase total production from about 43,000 tons to about 48,000 tons per year by yearend 1997. The Bangka Island tin smelter is a two-stage direct-reduction reverberatory furnace smelter fed with tin concentrates. Concentrating facilities are at Mentok. A Timah official stated that only about 5% of its tin metal production was for domestic use and that it now exports 47% of its output to Asia, 27% to Europe, and 21% to the North American market (Metal Bulletin, 1996g).

P.T. Koba Tin, 75%-owned by Renison Goldfields (Australia), announced the completion of construction of its 15,000-ton-annual-capacity tin smelter on Bangka Island. The first tin ingots from it were cast and shipped to customers early in 1996. This new smelter allows Koba Tin to smelt its own concentrates for the first time. Previously, Koba's tin mine output was smelted at the Mentok smelter of P.T. Tambang Timah, which owns 25% of Koba Tin. The new Koba Tin smelter will, therefore, free about 10,000 tons of annual capacity at the Mentok smelter for treatment of Timah's own concentrates.

Koba Tin announced that it had completed one of its major capital projects—the new Bemban dredge, in the western half of Koba's contract of work area. The dredge was operational by midyear and had increased the firm's annual production rate by 33%, to more than 10,000 tons of tin. The dredge reportedly was completed within its $16 million budget (Metal Bulletin, 1996d).

Korea, Republic of.—Nippon Steel Corp. (Japan) announced that it won a contract to construct a dual tinplate and tin-free plating line for Dongbu Steel Corp. at its new Asan Bay works, southwest of Seoul. Startup was expected by mid-1998. The new line would give Dongbu a combined tinplate and tin-free steel capacity of 380,000 tons per year when combined with the existing facilities at its Inchon works. The contract is Nippon Steel's first for a tinplate plant in South Korea, although Nippon has constructed similar facilities for Siam Tinplate in Thailand and Guangzhou Pacific Tinplate in China (Metal Bulletin, 1996a).

Kyrgyzstan.—The Kara Balta Mining Complex formed a joint venture with the Russian investment group Onyx to expand the Sary Dzhaz tin-tungsten project, where tin was being produced at the rate of 330 tons per year and tungsten at 220 tons per year. Onyx planned to invest $8 million in the project, and expected that by early 1997, the tin production rate would have been increased to 1,100 tons per year and the tungsten rate to 660 tons per year (Tin International, 1996d).

Malaysia.—In 1996, the bulk of tin production continued to come from gravel pump operations; only three dredges were operating. Although Malaysia's tin resources were believed to be still substantial, the Government discouraged tin mining until the price of tin shows a marked increase. The long-established tin producer, Petaling Tin Bhd, sought approval from the Selangor State Government to convert its core business of tin mining into property development. The firm has considerable tin holdings at Dengkil, and once approval is received, these would be converted into a mixed development of factories and housing. Malaysia's two large tin smelters continued to obtain most of their feedstock from foreign sources; the intake of tin concentrate increased by 6% to 67,000 tons. One of the smelters, Datuk Keramat Smelting, indicated that it may cease operations in Malaysia and operate solely through a newly acquired smelter, Thaisarco in Thailand. Tin consumption has been increasing in Malaysia, especially for use in solder, tinplate, and pewter. With domestic consumption at 6,000 tons per year, Malaysia is on the verge of becoming a net tin importer (Mining Journal, 1996).

Malaysia Smelting Corp. (MSC) completed a tripling of its annual capacity to produce high-purity 99.99% tin from about 120 to 360 tons per year. This was in response to current and future expected demand for high-purity tin, often from Asian electronics firms and especially from the Japanese transplants that have been set up in the "tiger" economies of Asia, such as Malaysia, the Republic of Korea, Taiwan and Thailand. MSC reportedly invested about $200,000 in the electrolytic treatment plant.

Peru.—Minsur's new $24 million tin smelter began production in the fall and was reportedly on target to produce tin metal at less than one-half of the industry's average cost. The smelter has a capacity of 15,000 tons per year of refined tin. Although some concerns were initially expressed in the industry regarding the viability of the Ausmelt Technology used in the smelter, refined tin production reached the 2,400-ton-per-year level by yearend, despite some startup problems. Commercial shipments of Grade A tin began, and the company expected to gain LME certification eventually for its tin brand. Minsur hoped that 1997 output would approach the full refined production capacity of 15,000 tons per year. Officials projected that capacity could reach 20,000 tons per year after oxygen enrichment equipment is installed. Once it reached near capacity, the new smelter was expected to smelt and refine tin concentrates at a cost of $300 per ton or less. This would be one-half of the $600 per ton that Minsur paid to have 12,000 tons of its own tin concentrate toll refined at the Vinto tin smelter in Bolivia in 1996. The world industry average smelting and refining cost is reported to be as much as $800 per ton of

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metal. Minsur officials expected that its total depreciation plus mine-through-refinery costs, already the world's lowest at $1,850 per ton, could decline to $1,180 per ton in 1998; this contrasts with an industry average of about $3,000 per ton. With the start of its own smelter, Minsur was in a position to reduce its tolling contracts. In 1995, all Minsur's mine output of 22,000 tons was toll refined at smelters in Asia and South America.

Portugal.—Early in the year, officials at the Neves Corvo copper/tin mine estimated that about 7,800 tons of tin concentrates, grading about 53% tin, equivalent to 4,100 tons of tin metal, would be produced at the mine in 1996. The Neves Corvo Mine is primarily a copper operation with a tin byproduct. The mine sells its tin concentrates to the three major Southeast Asian tin smelters—Malaysia Smelting Corp., Escoy Smelting Corp., and Thaisarco. Somincor owns 51% of the Neves Corvo Mine, and RTZ controls the rest (Tin International, 1996e).

Thailand.—Amalgamated Metal Corp. announced that it purchased the large Thaisarco tin smelter. Because Thaisarco had suffered declining tin concentrate supplies for several years, its tin production declined from 20,000 tons in 1989 to 8,000 tons in 1994. Its peak production had been 35,000 tons in 1980 (Tin International, 1996a).

United Kingdom.—South Crofty Holdings Ltd. announced that it had completed a major operational review of its South Crofty tin mine in Cornwall and now expected the mine to return to profitability in the near future. South Crofty Holdings, which acquired England's last remaining tin mine in 1994, raised $9 million in 1995 to fund an improvement program after a lack of capital prevented mine management from developing additional ore reserves. Late in 1995, an unexpected variability in ore grade had an adverse impact on the mine's production levels. Following an extensive diamond drilling program, production levels increased in 1996, with a resultant decrease in unit production costs. The tin grade at the mine currently averages 1.6%, compared with a grade of 1.2% in 1995, and mill recoveries have increased to 90% from 87% in 1995 (Metal Bulletin, 1996f).

AMG Resources Corp. Ltd. reported on developments in its British detinning operations. This British unit is a subsidiary of the American parent company of the same name. AMG reported that local government initiatives and roadside collection programs have resulted in an increasing number of used tin cans finding their way into the recycling chain. AMG officials projected that their Llanelli (Wales) detinning plant would treat about 25% more used tin cans in 1996 than in 1995. In 1995, this plant produced 80,000 tons of scrap steel from detinning new tinplate scrap and 20,000 tons from detinning used tin cans. AMG also operates a detinning plant in Hartlepool, United Kingdom. AMG reported that limited amounts of tin are recycled from tinplate at both plants and that at Llanelli, about 150 tons of tin are produced each year from used beverage cans. This tin generally takes the form of 99.99%-pure tin ingots. Although AMG's tin ingot is listed on the LME, the bulk of the material is sold directly to British tin alloy, copper wire, or solder operations. AMG officials are optimistic about the future of its British detinning operations, but they doubt if the detinning business will reach the levels achieved before aluminum beverage cans began to eat into tinplate's market share during the 1970's. Despite this, business has increased since the early 1990's when used tin can recycling programs began to accelerate (Metal Bulletin, 1996i).

Current Research and Technology

The International Tin Research Institute (ITRI), based in Uxbridge, United Kingdom, the world's foremost laboratory for tin scientific research and new tin applications, completed its second full year under its new structure. The ITRI is now privatized, with funding supplied by several major tin producer and user firms rather than by the ATPC. Solo Industries Ltd., (Sharhah, United Arab Emirates) became the 12th full member of ITRI Ltd. and the first consumer member. About 60% of current world tin production is represented by ITRI Ltd. members.

The Managing Director of ITRI Ltd. noted that it was actively searching for suitable lead-free solders for electronics, as a result of disposability problems. He noted the clear need for lead-free solders as consumers dispose of the ever-proliferating array of consumer electronics items, such as mobile phones and computers. ITRI completed its development of the Stanzec tin/zinc plating process. The resulting alloy could replace cadmium as a cheaper, less toxic anticorrosion coating on steel and was of interest to American automobile makers, according to the Managing Director. ITRI also is investigating alternatives to lead gun shot, which can pollute the environment; more than 60,000 tons of lead are fired from guns per year. ITRI has completed four ballistic trials by using tin gun shot; the results reportedly are promising. Another longer running ITRI project is an attempt to develop tin-based fire retardants. Zinc stannates and zinc hydroxystannate, developed by ITRI and manufactured by two British companies, contain about 46% tin and reportedly act as smoke retardants (Metal Bulletin, 1996h).

Aluminum Company of America (Alcoa) (Pittsburgh, PA) reported the development and patenting of a lead-free, cold-finished rod and bar aluminum alloy containing from 0.9% to 1.5% tin that allegedly provides good mechanical properties and the highest rating for machinability. Designated UltrAlloy 6020, the alloy also is said to have excellent corrosion resistance, anodizing response, and good brazability and weldability. Alcoa claims the alloy has finer chip formation than any other aluminum free-machining alloys and exhibits an enhanced surface finish after machining. These properties allow faster machining speeds and higher productivity. Typical applications include master cylinder brake pistons, connectors, transmission valves, and hydraulic components (Advanced Materials & Processes, 1996).

The Japan Research and Development Center for Materials, the Clean Japan Center, and Nikko Co. have jointly developed technology for efficiently sorting metal beverage cans. Their demonstration plant separates tinplate cans by a closed-type

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magnetic separator and aluminum cans by a multistage separator (JOM, 1996).

Researchers at the University of Connecticut announced development of a new technique to deal with the problem that some recycling of tin cans used as food containers is inefficient because enamel on the can masks nearly 50% of the tin. Observing that tin cans of all types represent an abundant source of steel scrap, with some 100 million containers being used and discarded daily, the researchers noted that proper detinning was crucial because a tin content of 0.35% could make steel brittle and less ductile. The researchers believe that the tin coating should be reduced by proper detinning to a level of 0.06% by weight. Using relatively high temperatures and concentrations of potassium stannate in their alkaline electrochemical detinning process, optimum removal of enamel and selective removal of tin from the steel can body is achieved (American Metal Market, 1996b).

Outlook

Domestic demand for primary tin is expected to grow slowly in the next few years, at a rate of perhaps 1% per year. If, however, new applications, especially those in which tin is substituted for toxic materials, find acceptance in the marketplace, then that rate could double by 2000.

There appears to be some evidence of interest in exploration and investment to develop world tin reserves, perhaps motivated by somewhat higher prices of tin in recent years. It seems likely that U.S. requirements for primary tin will continue to be met by imports and Government stockpile sales.

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TABLE 1
SALIENT TIN STATISTICS 1/

(Metric tons of contained tin, unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production:					
Mine	(2/)	(2/)	--	--	--
Secondary e/	13,700	12,000	11,700	11,600 r/	11,000
Exports, refined tin	1,890	2,600	2,560	2,790	3,670
Imports for consumption, refined tin	27,300	33,700	32,400	33,200	30,200
Consumption:					
Primary	35,000	34,600	33,700	35,200 r/	36,500
Secondary	10,100	11,900	8,530	10,800 r/	8,180
Stocks, yearend, U.S. industry	10,700	10,800	10,400	11,700 r/	11,800
Prices, average cents per pound:					
New York market	282.58	239.17	254.93	294.54	288.10
Platt's Metals Week composite	402.40	349.80	369.14	415.61	412.43
London	277.00	233.00	248.00	282.00	279.00
Kuala Lumpur	271.85	231.58	244.76	277.50	275.19
World: Production:					
Mine	191,000 r/	191,000 r/	182,000 r/	195,000 r/	196,000 e/
Smelter:					
Primary	194,000	193,000 r/	198,000 r/	201,000 r/	191,000 e/
Secondary	22,600 r/	19,800 r/	19,100 r/	18,900 r/	16,300 e/
Undifferentiated	2,150	1,320	322 r/	322 r/	320 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Negligible.

TABLE 2
U.S. CONSUMPTION OF PRIMARY AND SECONDARY TIN 1/

(Metric tons of contained tin)

	1995	1996
Stocks, Jan. 1 2/	8,480	9,180
Net receipts during year:		
Primary	39,400 r/	39,200
Secondary	5,020 r/	2,730
Scrap	6,240 r/	6,340
Total receipts	50,600 r/	48,300
Total available	59,100 r/	574,000
Tin consumed in manufactured products:		
Primary	35,200 r/	36,500
Secondary	10,800 r/	8,180
Total	46,000 r/	44,700
Intercompany transactions in scrap	123	169
Total processed	46,100 r/	44,800
Stocks, Dec. 31 (total available less total processed)	13,000 r/	12,600

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes tin in transit in the United States.

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TABLE 3
U.S. CONSUMPTION OF TIN, BY FINISHED PRODUCT 1/

(Metric tons of contained tin)

Product	1995			1996		
	Primary	Secondary	Total	Primary	Secondary	Total
Alloys (miscellaneous) 2/	W	W	W	W	W	W
Babbitt	589	282	871	617	234	851
Bar tin	1,200	W	1,200	1,150	W	1,150
Bronze and brass	1,080	1,750	2,830	1,100	1,660	2,760
Chemicals	7,060	W	7,060	7,520	W	7,520
Collapsible tubes and foil	W	W	W	240	W	240
Solder	10,800 r/	6,980 r/	17,700 r/	10,700	4,880	15,600
Tinning	1,110 r/	W	1,110 r/	2,030	W	2,030
Tinplate 3/	9,670	W	9,670	9,350	W	9,350
Tin powder	W	W	W	573	W	573
Type metal	W	W	W	W	W	W
White metal 4/	965	W	965	1,260	77	1,340
Other	2,770	1,780 r/	4,550 r/	1,900	1,320	3,230
Total	35,200 r/	10,800 r/	46,000 r/	36,500	8,180	44,700

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes terne metal.
3/ Includes secondary pig tin and tin acquired in chemicals.
4/ Includes pewter, britannia metal, and jewelers' metal.

TABLE 4
U.S. INDUSTRY YEAREND TIN STOCKS 1/

(Metric tons)

	1995	1996
Plant raw materials:		
Pig tin:		
Virgin 2/	7,660 r/	8,060
Secondary	718 r/	696
In process 3/	1,010	1,360
Total	9,390 r/	10,100
Additional pig tin:		
Jobbers-importers	1,240	1,440
Afloat to United States	1,040	211
Total	2,270	1,650
Grand total	11,700 r/	11,800

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes tin in transit in the United States.
3/ Data represent scrap only, tin content.

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TABLE 5
TIN RECOVERED FROM SCRAP PROCESSED IN
THE UNITED STATES, BY FORM OF RECOVERY 1/

(Metric tons, unless otherwise specified)

Form of recovery		1995	1996
Tin metal 2/		W	W
Bronze and brass e/ 3/		11,200 r/	10,800
Lead and tin alloys:			
Antimonial lead		335 r/	171
Babbitt		W	34
Type metal		39	37
Other alloys 4/		W	W
Total		374 r/	242
Tin content of chemical products		W	W
Grand total		11,600 r/	11,000
Value e/ 5/	thousands	$106,000 r/	$100,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes tin metal recovered at detinning and other plants.
3/ Includes tin recovered from copper-, lead-, and tin-base scrap.
4/ Includes foil, solder, terne metal, and cable lead.
5/ Based on Platt's Metals Week composite price.

TABLE 6
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF NEW AND OLD SCRAP AND TIN RECOVERED,
BY TYPE OF SCRAP 1/

(Metric tons)

	Gross weight of scrap								
	Stocks,		Consumption			Stocks,	Tin recovered e/ 2/		
Type of scrap	Jan. 1	Receipts	New	Old	Total	Dec. 31	New	Old	Total
1995:									
Copper-base scrap	6,570	127,000	27,200	100,000 r/	127,000 r/	6,350	1,170	3,680	4,850
Brass mills 3/	--	40,500	40,500	--	40,500	--	833	--	833
Foundries and other plants	2,730	26,800	W	W	W	3,100	W	703 r/	703 r/
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	2,010	4,380 r/	6,390 r/
Lead-base scrap r/	93,200	1,100,000	71,500	1,090,000	1,170,000	27,400	1,880	3,280	5,160
Tin-base scrap 4/	W	55	W	54	W	W	W	52	52
Grand total	XX	XX	XX	XX	XX	XX	3,880 r/	7,720 r/	11,600 r/
1996:									
Copper-base scrap	6,350	122,000	27,400	94,400	122,000	6,010	1,190	3,430	4,610
Brass mills 3/	--	45,900	45,900	--	45,900	--	885	--	885
Foundries and other plants	3,100	12,600	W	W	W	1,730	W	523	523
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	2,070	3,950	6,020
Lead-base scrap	25,600 r/	1,230,000	52,800	1,170,000	1,230,000	31,200	1,390	3,630	5,020
Tin-base scrap 4/	W	W	W	W	W	W	W	W	W
Grand total	XX	XX	XX	XX	XX	XX	3,460	7,580	11,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Tin recovered from new and old copper-base scrap, brass mills, and foundries.
3/ Brass-mill stocks include home scrap, and purchased-scrap consumption is assumed equal to receipts; therefore, line does not balance.
4/ Includes tinplate and other scrap recovered at detinning plants.

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TABLE 7
U.S. EXPORTS OF TIN IN VARIOUS FORMS 1/

Year	Tinplate and terneplate: Quantity (metric tons, gross weight)	Tinplate and terneplate: Value (thousands)	Ingots and pigs: Quantity (metric tons)	Ingots and pigs: Value (thousands)	Tin scrap and other tin bearing material except tinplate scrap 2/: Quantity (metric tons, gross weight)	Tin scrap and other tin bearing material except tinplate scrap 2/: Value (thousands)
1995	307,000	$185,000	2,790	$17,300	57,600	$56,600
1996	338,000	210,000	3,670	21,000	56,800	61,300

1/ Data are rounded to three significant digits.
2/ Includes rods, profiles, wire, powders, flakes, tubes, and pipes.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF TIN IN VARIOUS FORMS 1/

Year	Miscellaneous 2/: Value (thousands)	Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.: Quantity (metric tons, gross weight)	Dross, skimmings, scrap, residues, tin alloys, n.s.p.f.: Value (thousands)	Tinplate and terneplate: Quantity (metric tons, gross weight)	Tinplate and terneplate: Value (thousands)	Tin compounds: Quantity (metric tons, gross weight)	Tin compounds: Value (thousands)	Tinplate scrap: Quantity (metric tons, gross weight)	Tinplate scrap: Value (thousands)
1995	$5,050	24,800	$58,900	272,000	$180,000	986	$7,270	16,000	$2,390
1996	5,070	16,000	58,800	251,000	161,000	354	3,120	64,600	5,690

1/ Data are rounded to three significant digits.
2/ Includes tinfoil, tin powder, flitters, metallics, manufactures, n.s.p.f.

Source: Bureau of the Census.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT TIN METAL, BY COUNTRY 1/

Country	1995: Quantity (metric tons)	1995: Value (thousands)	1996: Quantity (metric tons)	1996: Value (thousands)
Australia	--	--	222	$1,260
Bolivia	6,630	$40,300	6,290	39,200
Brazil	8,070	50,500	9,460	58,500
Canada	185	1,270	270	1,720
Chile	469	2,840	407	2,440
China	5,610	34,200	2,760	16,000
Hong Kong	134	1,260	--	--
India	146	844	898	5,720
Indonesia	7,230	44,600	7,550	47,000
Korea, Republic of	219	1,090	10	--
Malaysia	3,810	23,200	965	6,760
Netherlands	60	411	--	--
Peru	--	--	481	2,850
Russia	149	926	435	2,760
Singapore	40	385	120	750
United Kingdom	97	632	243	1,550
Other	306	2,000	57	441
Total	33,200	204,000	30,200	187,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 10
TIN: WORLD MINE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Australia 3/	6,609	8,057	7,100	8,656 r/	8,828 4/
Bolivia	16,516	18,634	16,169 r/	14,419	15,200
Brazil	27,000 r/	26,900 r/	20,400 r/	19,500 r/	19,500
Burma 5/	649	689	814	747	420
Burundi e/	110	10 r/	10 r/	-- r/	(6/)
Cameroon e/	3	3	2	2	1
China e/	43,800	49,100	54,100	61,900 r/	60,000
Indonesia	29,400	29,000 e/	30,610	38,378	38,500
Kazakstan e/	75	50	24	15	15
Laos e/	300	300	200	200	200
Malaysia	14,339	10,384	6,458	6,402	5,174 4/
Mexico	1	3	3 e/	1	2
Mongolia e/	190	150	100	150	100
Namibia	11	4	1	2	-- 4/
Niger e/	20	20	20	20	20
Nigeria 7/	415	400 e/	185	185 e/	150
Peru	10,044	14,310	20,275 r/	22,331	27,004 4/
Portugal	6,560	5,334 r/	4,332 r/	4,627 r/	4,800
Russia	15,160	13,100	10,460	9,000 e/	8,000
Rwanda e/	500	400	50	--	--
South Africa	582	450 e/	--	--	--
Spain	7	2	4	2 e/	2
Tanzania e/	8	11	4 4/	--	--
Thailand	11,484	6,363	3,926	2,201 r/	1,450
Uganda e/	30 4/	30	30	30	30
United Kingdom	2,044	2,232	1,922	1,973 r/	2,103 4/
United States	W	W	--	--	--
Vietnam e/	3,400	3,500	4,000	4,500	4,500
Zaire	1,020	700 e/	1,000	-- r/	--
Zambia	2	2 e/	--	--	--
Zimbabwe e/	950	800	82 4/	--	--
Total	191,000 r/	191,000 r/	182,000	195,000 r/	196,000

e/ Estimated. r/ Revised. W Witheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 25, 1997.

3/ Excludes tin content of copper tin and tin tungsten concentrates.

4/ Reported figure.

5// Includes content of tin tungsten concentrate.

6/ Less than 1/2 unit.

7/ Concentrate gross weight reported, estimated 62% Sn content.

TABLE 11
TIN: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Argentina: e/					
Primary	140	145	100	100	100
Secondary	100	100	100	100	100
Total	240	245	200	200	200
Australia:					
Primary	240	222	315	570	460 3/
Secondary e/	360	250	260	300	300
Total e/	600	472	575	870	760
Belgium: Secondary e/	5,260	5,000	5,000	5,000	3,000
Bolivia: Primary	14,393	14,541	15,285	17,709	16,000
Brazil:					
Primary	27,000	26,900	20,400	19,500 r/	19,500
Secondary e/	250	250	250	250	250
Total e/	27,300	27,200	20,700	19,800 r/	19,800
Bulgaria: Primary and secondary	23	23	22	22 e/	20

See footnotes at end of table.

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TABLE 11--Continued
TIN: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Burma: Primary	189	170	200 e/	190 r/ e/	100
Canada: Secondary e/	200	200	--	--	--
China: Primary e/	39,600	52,000	67,800	62,100 r/	55,800
Czech Republic: Primary and secondary e/ 4/	XX	115	100	100	100
Czechoslovakia: 5/ Primary	115	XX	XX	XX	XX
Denmark: Secondary e/	100	100	100	100	100
Germany: Primary and secondary	127	179	100	100 e/	100
Greece: Secondary e/	200	200	150	150	100
India: Secondary e/	200	200	200	100	200
Indonesia: Primary	31,915	30,415	31,100 e/	38,628	39,000
Japan: Primary	821	804	706	630	524 3/
Korea, Republic of: Primary e/	400	400	300	300	300
Malaysia: Primary	45,598	40,079 r/	37,990 r/	39,433 r/	38,051 3/
Mexico: Primary	2,590	1,640	768	770	770
Netherlands: Secondary e/	200	--	--	--	--
Nigeria: Primary	370	350	179 r/	175 r/ e/	175
Norway: Secondary e/	90	90	90	70 r/	50
Portugal: Primary and secondary e/	2,000	1,000	100 r/	100 r/	100
Russia: e/					
Primary	15,200	13,400	11,500	9,500	9,000
Secondary	1,500	1,000	1,000	1,000	1,000
Total	16,700	14,400	12,500	10,500	10,000
South Africa: 6/					
Primary	592	452	43	-- r/	--
Secondary e/	60	45	--	--	--
Total e/	652	497	43	-- r/	--
Spain: e/					
Primary	600	500	500 r/	500 r/	150
Secondary	200	200	200	100 r/	50
Total	800	700	700 r/	600 r/	200
Thailand: Primary	10,679	8,099	7,759	8,243	8,000
United Kingdom: Secondary e/	100	100	100	100	100
United States: Secondary	13,700 r/	12,000 r/	11,700 r/	11,600 r/	11,000 3/
Vietnam: Primary e/	2,400	2,500	2,500	2,800	2,800
Zaire: Primary e/	50	20	20	15	15
Zimbabwe: Primary	716	657	82	--	--
Grand total	218,000 r/	214,000 r/	217,000 r/	220,000 r/	207,000
Of which:					
Total primary	194,000	193,000	198,000	201,000	191,000
Total secondary	22,600 r/	19,800 r/	19,100 r/	18,900 r/	16,300
Total undifferentiated	2,150	1,320	322 r/	322 r/	320

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Wherever possible, total smelter output has been separated into primary (from ores and concentrates) and secondary (tin metal recovered from old scrap). This table reflects metal production at the first measurable stage of metal output. Table includes data available through June 25, 1997.

3/ Reported figure.

4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

5/ Dissolved Dec. 31, 1992. All production for Czechoslovakia in 1992 came from the Czech Republic.

6/ South Africa's only operating tin mine closed in early 1994.

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TITANIUM

By Joseph Gambogi

Titanium occurs primarily in the minerals anatase, brookite, ilmenite, leucoxene, perovskite, rutile, and sphene. Of these minerals, only ilmenite, leucoxene, and rutile have significant economic importance. As a metal, titanium is well known for corrosion resistance and for its high strength-to-weight ratio. However, approximately 95% of titanium is consumed in the form of titanium dioxide (TiO_2), a white pigment in paints, paper, and plastics. Other end uses of titanium include ceramics, chemicals, welding rod coatings, heavy aggregate, and steel furnace flux.

Global consumption of TiO_2 was nearly unchanged in 1996 compared with 1995. U.S. production and apparent consumption of TiO_2 pigment decreased, 2% and 1%, respectively. In contrast to the pigment industry, the titanium metal industry experienced high growth in demand. Demand from commercial aerospace and golf club markets resulted in a near record year for titanium metal production. U.S. production and shipments of ingot increased by 29% and 26%, respectively, compared with those of 1995. *(See table 1.)*

Legislation and Government Programs

The U.S. Government's National Defense Stockpile (NDS) held 33,200 metric tons of titanium sponge at yearend. In accordance with the National Defense Authorization Act for fiscal year 1996, Public Law 104-106, Section 3305, 227 tons (250 short tons) of titanium sponge from the NDS was transferred to the U.S. Army during 1996. The material was designated for use in the weight reduction program of the main battle tank upgrade program.

The U.S. Department of Commerce, International Trade Administration (ITA) published the final results of an antidumping review for imports of titanium sponge from Russia. The review covered imports from Berezniki Titanium-Magnesium Works (AVISMA), Interlink Metals and Chemicals, Inc., and Cometals Inc. during the period August 1, 1994, through July 31, 1995. Under the review, the ITA concluded that AVISMA, a producer of titanium sponge, would continue to be subject to the Russia-wide 83.96% antidumping margin. However, the ITA determined the margin for the two trading companies, Interlink and Cometals, would be revised to 0% and 28.31%, respectively (U.S. Department of Commerce, International Trade Administration, 1996).

Production

Ores and Concentrates.—Commercial forms of titanium ores and concentrates include ilmenite, leucoxene, rutile, titanium slag, and synthetic rutile. Australia, Canada, Norway, and South Africa are the major producing countries of titanium ores and concentrates. U.S. producers of titanium concentrates include E. I. du Pont de Nemours & Co. Inc. (DuPont), Kerr-McGee Chemical Corp., RGC (USA) Mineral Sands, Inc. (RGC), and P.W. Gillibrand Co. DuPont's Trail Ridge mining operations in Starke, FL, produce a mixed product containing rutile, leucoxene, and ilmenite that is used as a feedstock in DuPont's titanium pigment operations. RGC's mining operation in Green Cove Springs, FL, produces both rutile and ilmenite concentrates. P.W. Gillibrand produces ilmenite concentrate as a byproduct of its sand and gravel operation in Simi Valley, CA. Kerr McGee's operation in Mobile, AL, produces synthetic rutile from purchased ilmenite concentrate. Titanium slag is not produced in the United States.

RGC announced plans to proceed with the development of the Old Hickory deposit located south of Richmond, VA. RGC plans included new capacity to produce up to 100,000 tons per year of ilmenite (59% to 60% TiO_2), 3,500 tons per year of a "high grade" titanium feedstock (85% TiO_2), and 30,000 tons per year of zircon. Construction of mining and separation facilities was expected to be completed in 1997 (RGC Ltd., 1997).

Metal.—Titanium sponge is the elemental form of titanium metal. Production involves the chlorination of titanium-containing ores to produce titanium tetrachloride. Titanium tetrachloride is purified and then reacted with magnesium to produce titanium sponge. Titanium sponge is produced in China, Japan, Kazakstan, Russia, and the United States. U.S. producers of titanium sponge include Oregon Metallurgical Corp. (Oremet), Albany, OR, and Titanium Metals Corp. (Timet), Henderson, NV. Domestic sponge production capacity is estimated to be 29,500 tons per year. However, only 21,300 tons per year is currently active because of Timet's ability to recycle magnesium is smaller than required to utilize its full production capacity. In 1996, U.S. production of titanium sponge was withheld to avoid disclosing company proprietary data. *(See table 2.)*

Titanium ingot is produced by melting titanium sponge or scrap or a combination of both, usually with various other alloying elements such as vanadium and aluminum. Electron-beam, plasma, and vacuum-arc-reduction are the current commercial melting methods used to produce ingot. Currently, ingot production capacity exists in France, Germany, Japan, Russia, the United Kingdom, and the United States. In the United States, ingot is produced by the two sponge producers, Oremet and Timet, and by seven other firms. U.S. production and shipments of ingot increased by 29% and 26%, respectively,

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compared with those of 1995. *(See table 3.)*

Titanium mill products result from the drawing, forging, and rolling of titanium ingots or slabs into products of various sizes and grades. These mill products include titanium billet, bar, rod, wire, plate, sheet, strip, extrusions, pipe and tube, etc. Producers of titanium mill products are located primarily in the China, Europe, Japan, Russia and the United States. Over 30 companies are known to produce titanium mill products and castings in the United States. In 1996, U.S. production of mill products increased by 32%, compared with the 1995 level.

Titanium castings are produced by melting titanium ingot or billet and then pouring the molten metal into a mold. U.S. producers of titanium castings include Coastcast Corp., Rancho Dominguez, CA; Duriron Co., Dayton, OH; Howmet Corp., Whitehall, MI; Investicast, Ltd., Sweet Home, OR; Precision Cast Parts Corp., Portland, OR; Selmet Inc., Albany, OR; Timet Castings Corp., Albany, OR; and Wyman-Gordon Investment Castings, Inc., Groton, CT.

Ferrotitanium is produced through induction melting of titanium scrap with iron or steel. U.S. producers of ferrotitanium include Galt Alloys Inc., Canton, OH, and Shieldalloy Metallurgical Corp., Newfield, NJ. The two standard grades of ferrotitanium contain 40% and 70% titanium. Data on production of ferrotitanium were not available.

In 1996, Johnson Matthey Electronics' Alta Group commissioned a 340-ton-per-year titanium sponge manufacturing facility in Salt Lake City, UT. Unlike other domestic producers, the Alta facility uses sodium rather than magnesium to reduce titanium tetrachloride to titanium sponge. Sponge production from the facility will supply the electronic industry with raw material for the production of electronic-quality, high-purity, titanium crystal (The Alta Group, 1996).

A 50-50 joint venture between Sturm, Ruger & Co. and Callaway Golf Co. named Antelope Hills, LLC, was in the process of constructing a titanium foundry in Prescott, AZ. The new foundry was scheduled to be completed in 1997 and was expected to produce titanium golf club heads (Sturm, Ruger, & Company, Inc., 1997).

Owing to increased demand for titanium sponge, Timet reactivated the idle Kroll plant at its Henderson, NV, facility. In 1993 the Kroll plant was idled when Timet opened its 10,000-ton-per-year vacuum distillation process plant at Henderson (Titanium Metals Corp., 1997).

Timet acquired nearly all of the assets of Axel Johnson Metals Inc. (AJM), a subsidiary of Axel Johnson Inc. Consequently, Titanium Hearth Technologies (THT), the joint venture between Timet and AJM, is now wholly owned by Timet. In addition to the THT melting operations, Timet acquired AJM melting and scrap processing operations in California and Pennsylvania. The acquired THT and AJM melting facilities produce titanium ingot via electron- beam and vacuum-arc-reduction melting. In a separate acquisition, Timet acquired IMI plc.'s titanium castings operations in Albany, OR, and Pomona, CA (Titanium Metals Corp., 1997).

Pigment.—Titanium dioxide pigment is produced using either the chloride process or the sulfate process. Either route may be used to produce rutile-grade or anatase-grade pigments. U.S. producers of titanium dioxide pigments are DuPont, Kemira Inc., Kerr-McGee, Louisiana Pigment Co. LP, and SCM Chemicals Inc. U.S. production of TiO_2 pigment in 1996 decreased slightly compared with that of 1995. Capacity utilization for the domestic pigment industry was about 83%. *(See tables 4 and 5.)*

In 1996, SCM Chemicals announced plans to curtail sulfate-route capacity in Baltimore, MD, to 44,000 tons per year. Capacity of the 51,000-ton-per-year chloride-route plant at the Baltimore facility was not expected to be affected (Millennium Chemicals Inc., 1997).

Consumption

Ores and Concentrates.—On a gross weight basis, U.S. reported consumption of TiO_2 in ilmenite and titanium slag was 1.4 million tons, a slight decrease compared with the 1995 level. Meanwhile, consumption of natural and synthetic rutile decreased 17%.

Consumption data for titanium concentrates are developed by the U.S. Geological Survey (USGS) from one voluntary survey of domestic operations. Of the 28 operations canvassed, 22 responded, representing 99% of the data in table 6. Data for nonrespondents were estimated based on prior-year consumption levels. *(See table 6.)*

Metal.—Increased ingot production caused titanium sponge and scrap consumption to increase by 32% and 28%, respectively, compared with those of 1995. Scrap supplied a calculated 51% of ingot feedstock. Increased demand for titanium mill products by the commercial aerospace and nonaerospace markets resulted in a 25% increase in ingot consumption and a 31% increase in mill product shipments. Reported shipments of titanium castings increased 42%. Estimated U.S. mill product usage by application was as follows: commercial aerospace, 45%; military aerospace, 15%; and nonaerospace uses, 40%. Nonaerospace uses include those in the specialty chemical, pulp and paper, oil and gas, marine, medical, and consumer goods industries. Reported consumption of titanium products in steel and other alloys increased significantly compared with 1995. *(See tables 3 and 7.)*

Pigment.—Rutile-grade and anatase-grade are the two crystal forms of titanium pigment. The three largest end uses are paint and coatings, paper, and plastics. Other consuming industries included ceramics, fabrics and textiles, floor coverings, printing ink, and rubber. Apparent domestic consumption of TiO_2 pigments was about 1.07 million tons, nearly unchanged compared with that of 1995. *(See tables 5 and 8.)*

Stocks

Based on TiO_2 content, consumer inventories of titanium ores and concentrates increased 82% compared with that of 1995. On a gross weight basis, producer stocks of TiO_2 pigment were about 107,000 tons, an 11% decrease from the 1995 level.

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Industry stocks of sponge decreased 17% while stocks of titanium ingot and scrap increased 32% and 69%, respectively. *(See table 9.)*

Prices

Published prices for titanium concentrates, pigments, and metal are presented in table 10. Prices for bulk natural rutile concentrates decreased about 6% compared with those of 1995. However, bagged rutile concentrates used in the welding rod coatings market increased 8%. Ilmenite prices also increased moderately. Published prices for titanium slag were not available. However, based on the U.S. Customs value of imports, prices for Canadian slag increased 20% while prices for South African slag increased slightly. Although there was increased demand for titanium products, published prices for titanium sponge were unchanged. While demand for titanium pigment was nearly unchanged, published prices for titanium pigment increased significantly compared with those of 1995. *(See table 10.)*

Foreign Trade

Ores and Concentrates.—The United States is highly import dependent for titanium concentrates. During 1996 the largest import sources of titanium concentrates were Australia, India, and South Africa. Annual imports of ilmenite, slag, and synthetic rutile concentrates increased 10%, 9%, and 12%, respectively, compared with those of 1995. Meanwhile, imports of natural rutile decreased 5%. *(See tables 11 and 12.)*

Metal.—U.S. import reliance extends to titanium metal, primarily in the form of titanium sponge and scrap. Although a significant quantity of imported titanium scrap is consumed by the iron and steel industry, nearly all of the imported sponge is consumed by the titanium industry. Sponge and scrap imports increased significantly in 1996. The leading import sources of titanium sponge were China, Japan, Kazakstan, and Russia. The leading import sources of titanium waste and scrap were Italy, Japan, Russia, and the United Kingdom. *(See table 13.)*

Pigment.—The United States is a net exporter of titanium pigments. However, a significant quantity of titanium pigments is imported. During 1996, the leading import sources of titanium pigments were Canada and Germany. Imports of titanium pigments containing more than 80% TiO_2 and other pigments decreased 14% and 2%, respectively, compared with those of 1995. Imports of titanium oxide increased 8%. *(See table 14.)*

World Review

World production of titanium concentrates, excluding the United States, was estimated to have increased slightly compared with that of 1995. However, the absence of Sierra Leone as a major producer of natural rutile continued to affect world markets. Increased production of ilmenite and titaniferous slag, primarily from Australia and Canada, offset the depressed rutile production. Slag production increased 7% on a gross weight basis. *(See table 15.)*

Australia.—Australian titanium mineral sands producer RGC Ltd. acquired controlling interest in Cudgen RZ Ltd. Through the acquisition, RGC now holds controlling interest in fellow mineral sands producer Consolidated Rutile Ltd (CRL). CRL is one of the largest titanium mineral producers in Australia. In April, RGC commissioned its Synthetic Rutile Enhancement Process (SREP) at its Narngulu synthetic rutile plant. The SREP is a modification of the Becher process through the introduction of flux as a kiln additive. The SREP decreases radioactivity and increases the TiO_2 content of synthetic rutile production (RGC Ltd., 1997).

After 8 years of production, CRL's dredging operations on North Stradbroke Island, Australia, exhausted the Bayside deposit. CRL planned to begin production from the Ibis-Alpha deposit on North Stradbroke Island in 1997 (RGC Ltd., 1997).

Tioxide closed its Burnie, Tasmania, TiO_2 pigment facility. The sulfate-route plant had been in operation for 48 years with a recent capacity of 26,000 tons per year. Owing to poor market conditions, the company postponed plans to construct a 20,000-ton-per-year plant in Whyalla, Western Australia (Sulphur, 1996).

Canada.—Solv-Ex Corp. obtained permits from the Alberta Ministry of Energy to proceed with a project to produce 14,000 barrels per day of oil with coproduction of minerals from the Athabasca tar sands deposit in northern Alberta. According to Solv-Ex, mineral production from the operation could be a significant source of TiO_2 (North American Minerals News, 1996).

Tiomin Resources Inc. completed preliminary reserve estimates in the North Zone area of the Natashquan deposit. According to the company, proven reserves in two blocks of the concession area are 277 million tons with 5.9% heavy minerals. Several geophysical and drilling programs were underway during the year (Tiomin Resources Inc., 1996).

Finland.—The Ministry of Trade of Finland offered an invitation to tender for the rights to conduct investigations and commercial development of the Kalvia ilmenite deposit near Kokkola. According to the Geological Survey of Finland, the deposit contains 44 million tons of resources to a depth of 150 meters with 15% ilmenite and 5% to 6% magnetite (Industrial Minerals, 1996c).

Japan.— According to the Japan Titanium Society, Japan's titanium sponge and ingot production in 1996 were 21,062 tons and 13,887 tons, respectively. Exports of titanium sponge were 10,637 tons, a 98% increase compared with those of 1995. Mill product shipments were 9,555 tons of which 5,218 tons was exported.

Kenya.—Tiomin Resources Inc. acquired an 80% interest in the licensed mineral rights of four prospecting areas along the Kenyan coast. According to the company, drilling in the four areas has delineated a resource of 3 billion tons of titanium-bearing sands. A prefeasibility study was scheduled to be completed by midyear 1997 (Tiomin Resources Inc., 1996).

Mozambique.—Kenmare Resources and BHP Minerals

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signed a joint-venture agreement to explore and possibly develop the Congolone deposit in Mozambique. During work performed under a previous memorandum of understanding between the two companies, the deposit was estimated to contain a resource of 50.5 million tons of ilmenite (Industrial Minerals, 1996a).

Sierra Leone.—In 1996, mining operations at Sierra Rutile Ltd.'s (SRL) mining operations at Moyamaba remained idle. In 1995, rebel forces overtook SRL mining operations. Although Government forces later regained control of the operation, mining operations were suspended indefinitely. At that time the operation was the largest single producer of rutile in the world with a capacity of 150,000 tons per year.

South Africa.—In the fourth quarter, an explosion halted production at Namakwa Sands Ltd.'s titanium slag facility at Brand-se-Baai. The explosion was caused by water coolant leaking into roof of the plasma-arc furnace. Production of rutile and zircon concentrates from Namakwa's nearby minerals separation plant was not affected, and slag production was expected to resume in early 1997 following repairs to the furnace lining (Industrial Minerals, 1997d).

United Kingdom.—SCM Chemicals announced plans to close 10,000 tons per year of sulfate-route TiO_2 pigment capacity but expand the chloride-route capacity at its Stallingworth facility to 150,000 tons per year by 1998. This expansion follows a recent expansion that brought the facility to 109,000 tons per year (Chemical Week, 1996).

Vietnam.—Bimal Minerals Co. completed construction and commenced production of heavy minerals concentrate at its wet separation plant at Cat Khahn in the Binh Dinh Province. Bimal is a joint venture between Binh Dinh Minerals Co., Malaysia Mining Co., and Pendorong Co. Bimal plans to truck the concentrate from the wet separation plant to its existing dry separation plant in Degi. Initial production was expected to be 4,000 tons per month of ilmenite (Industrial Minerals, 1996b).

Outlook

Ores and Concentrates.—The demand for titanium ores and concentrates is largely driven by the demand for titanium pigments, which follows general economic growth. Requirements by the pigment industry point toward an increased reliance on high-grade feedstocks (high-grade ilmenite, rutile, and slag) suitable for use in chloride-route pigment production. In addition, growing concern over the presence of naturally occurring radioactivity in mineral deposits will affect exploration efforts in the coming years. In the short term, the loss of Sierra Leone as a major supplier of natural rutile is expected to affect the availability and price of high-grade ores and concentrates. However, the development of new deposits and processing technology should provide for moderate growth over the next decade.

Pigment.—Since TiO_2 pigments are used in paints and coatings, paper, and plastics, demand for TiO_2 pigment generally follows the growth of the economy as a whole. However, trends within individual market sectors affect demand for TiO_2 pigments. In the paint and coatings industry, expected growth in home ownership and increased use of bright glossy finishes are expected to increase demand for TiO_2 pigments. In the paper industry, demand for lighter paper and increased paper recycling are expected to increase demand for pigments. Increased substitution by plastics for traditional materials is expected to increase demand for TiO_2 pigments by the plastics industry. Although global consumption of TiO_2 was nearly unchanged in 1996 compared with that of 1995, pigment demand is forecast to grow by 3% over the next several years.

Metal.—Demand for titanium metal products historically has been driven by the commercial and military aerospace markets. Since 1995, demand for titanium metal has increased significantly. The titanium industry has improved due to a combination of factors including a surge in commercial aerospace demand, moderate growth in industrial demand, and the new use of titanium in golf club heads. Demand for new aircraft and replacement parts should continue to drive demand for titanium metal over the next few years. However, long-term growth rates are expected to be dependent on nonaerospace markets such as consumer goods, medical, oil and gas, and military armor.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT TITANIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Ilmenite and titanium slag:					
Imports for consumption	832,000	777,000	808,000	861,000	939,000
Consumption 2/	1,220,000	1,240,000	W	1,410,000	1,400,000
Rutile concentrate, natural and synthetic:					
Imports for consumption	317,000	371,000	332,000	318,000	324,000
Consumption	461,000	465,000	510,000	480,000	398,000
Sponge metal:					
Production	W	W	W	W	W
Imports for consumption	684	2,160	6,470	7,560	10,100
Consumption	14,200	15,100	17,200	21,500	28,400
Price, Dec. 31, per pound	$3.50-$4.00	$3.50-$4.00	$3.75-$4.25	$4.24-$4.50	4.25-$4.50
Titanium dioxide pigment:					
Production	1,140,000	1,160,000	1,250,000	1,250,000	1,230,000
Imports for consumption	169,000	172,000	176,000	183,000	167,000
Consumption, apparent 3/	1,000,000	1,030,000	1,090,000	1,080,000	1,070,000
Price, Dec. 31, cents per pound:					
Anatase	99	99	94-96	92-96	1.06-1.08
Rutile	92-95	92-95	92-94	99-103	1.08-1.10
World production:					
Ilmenite concentrate 4/	3,920,000 r/	4,000,000 r/	3,050,000 r/	3,970,000 r/	3,990,000 e/
Rutile concentrate, natural 4/	491,000 r/	501,000 r/	546,000 r/	416,000 r/	415,000 e/
Titaniferous slag	1,640,000	1,550,000	1,510,000	1,810,000	1,940,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; except prices.

2/ Includes consumption to produce synthetic rutile.

3/ Production plus imports minus exports plus stock decrease or minus stock increase.

4/ Excludes U.S. production data to avoid disclosing company proprietary data.

TABLE 2
U.S. TITANIUM METAL PRODUCTION CAPACITY IN 1996 1/

		Yearend capacity (metric tons)	
Company	Plant location	Sponge	Ingot 2/
Allvac	Monroe, NC	--	9,500 3/
Howmet Corp.,Titanium Ingot Div.	Whitehall, MI	--	3,200
Lawrence Aviation Industries Inc.	Port Jefferson, NY	--	1,400
Oregon Metallurgical Corp. (Oremet)	Albany, OR	6,800	10,000
RMI Titanium Co.	Niles, OH	--	16,300
Titanium Hearth Technologies Inc.	Morgantown, PA	--	13,600 4/
	Verdi, NV	--	2,700 4/
Titanium Metals Corp.	Henderson, NV	22,700	15,900
	Pomona, CA	--	2,000
Wah Chang	Albany, OR	--	900
Wyman-Gordon Co.	Worcester, MA	--	2,300
Total		29,500	77,800

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Based on 7-day-per-week full production. Includes 59,200 tons vacuum-arc double-triple melt, of which triple melt generally ranged from 10% to 30%. The remaining 18,600 tons was cold hearth (electron-beam and plasma) capacity.

3/ Includes 2,300 tons of cold hearth capacity.

4/ Cold hearth.

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TABLE 3
COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND 1/

(Metric tons)

Component	1995	1996
Production:		
Sponge	W	W
Ingot	39,800	51,400
Mill products	23,300	30,700
Exports:		
Sponge	225	528
Other unwrought	603	471
Scrap	3,420	3,410
Ingot, slab, sheet bar, etc.	1,960	3,820
Other articles of titanium	4,580	4,530
Total	10,800	12,800
Imports:		
Sponge	7,560	10,100
Scrap	11,100	16,400
Ingot and billet	1,880	2,590
Other unwrought	1,180	595
Other wrought (mill products)	1,600	5,890
Other articles of titanium	272	261
Total	23,600	35,800
Stocks, yearend:		
Government: Sponge (total inventory)	33,400	33,200
Industry:		
Sponge	5,270	4,390
Scrap	9,430	15,900
Ingot	3,560	4,710
Other	W	W
Total industry	18,300	25,000
Reported consumption:		
Sponge	21,500	28,400
Scrap	20,500	26,300
Receipts:		
Home	11,800	14,400
Purchased	18,000	24,500
Ingot	30,600	38,300
Mill products (net shipments):	19,800	25,900
Forging and extrusion billet	8,820	11,200
Rod and bar	2,770	3,100
Other 2/	8,180	11,600
Castings (shipments)	479	680

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Data for sheet and strip, plate, extrusions (other than tubing), pipe and tubing, and other have been combined to avoid disclosing company proprietary data.

TABLE 4
CAPACITIES OF U.S. TITANIUM DIOXIDE PIGMENT PLANTS ON DECEMBER 31, 1996 1/ 2/

		Yearend capacity (metric tons per year)		
Company	Plant location	Sulfate process	Chloride process	Total
E. I. du Pont de Nemours & Co. Inc.:	Antioch, CA	--	36,000	36,000
	De Lisle, MS	--	280,000	280,000
	Edge Moor, DE	--	128,000	128,000
	New Johnsonville, TN	--	320,000	320,000
Kemira, Inc.	Savannah, GA	54,000	91,000	145,000
Kerr-McGee Chemical Corp.	Hamilton, MS	--	145,000	145,000
Louisiana Pigment Co. LP	Lake Charles, LA	--	110,000	110,000
SCM Chemicals Inc.	Ashtabula, OH	--	190,000	190,000
Do.	Baltimore, MD	66,000	51,000	117,000
Total		120,000	1,350,000	1,470,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Table does not include Hitox Corp.'s Corpus Christi, TX, production capacity of about 16,400 tons per year of buff TiO_2 pigment that is produced by refining and fine grinding of synthetic rutile.

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TABLE 5
COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND 1/

(Metric tons unless otherwise specified)

		1995		1996	
		Gross weight	TiO2 content	Gross weight	TiO2 content
Production 2/		1,250,000	1,180,000	1,230,000	1,160,000
Shipments: 3/					
Quantity		1,330,000	1,210,000	1,330,000	1,250,000
Value	thousands	$2,540,000	$2,540,000	$2,520,000	$2,520,000
Exports		342,000	321,000 e/	332,000	312,000 e/
Imports for consumption		183,000	172,000 e/	167,000	157,000 e/
Stocks, yearend		120,000	113,000 e/	107,000	100,000 e/
Consumption, apparent 4/		1,080,000	1,020,000 e/	1,070,000	1,010,000 e/

e/ Estimated.

1/ Data are rounded to three significant digits.

2/ Excludes production of buff pigment.

3/ Includes interplant transfers.

4/ Production plus imports minus exports plus stock decrease or minus stock increase.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 6
U.S. CONSUMPTION OF TITANIUM CONCENTRATES 1/

(Metric tons)

	Ilmenite and titanium slag 2/ 3/		Rutile (natural and synthetic)	
	Gross weight	TiO2 content	Gross weight	TiO2 content
1995:				
Pigments	1,410,000 r/	1,010,000 r/	453,000	417,000
Miscellaneous 4/	(5/)	(5/)	27,300	22,300
Total	1,410,000	1,010,000	480000	439000
1996:				
Pigments	1,400,000	1,010,000	372,000	341,000
Miscellaneous 4/	(5/)	(5/)	26,400	24,200
Total	1,400,000	1,010,000	398000	365000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

3/ Includes ilmenite consumed to produce synthetic rutile.

4/ Includes alloys, carbide, welding-rod coatings and fluxes, ceramics, chemicals, glass fibers, synthetic rutile, and titanium metal.

5/ Included with "Pigments" to avoid disclosing company proprietary data.

TABLE 7
U.S. CONSUMPTION OF TITANIUM PRODUCTS 1/ 2/
IN STEEL AND OTHER ALLOYS

(Metric tons)

	1995	1996
Carbon steel	2,340	3,090
Stainless and heat-resisting steel	1,600	1,550
Other alloy steel (includes HSLA)	533 r/	690
Tool steel	W	W
Total steel	4,460 r/	5,330
Cast irons	W	W
Superalloys	734	747
Alloys, other than above	384	63
Miscellaneous and unspecified	132	1,170
Total consumption	5,710 r/	7,310

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

1/ Includes ferrotitanium, titanium scrap, and other titanium additives.

2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 8
U.S. DISTRIBUTION OF DOMESTIC TITANIUM PIGMENT SHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY

(Percent)

Industry	1995	1996
Ceramics	0.3	W
Coated fabrics and textiles	.3	W
Floor coverings	1.0	0.3
Paint, varnish, lacquer	46.9	48.1
Paper	24.8	W
Plastics	17.7	19.0
Printing ink	1.3	.4
Roofing granules	W	W
Rubber	1.5	1.2
Other 1/	6.2	31.0
Total	100.0	100.0

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, and paper.

TABLE 9
U.S. STOCKS OF TITANIUM CONCENTRATES AND PIGMENT, DECEMBER 31 1/

(Metric tons)

	1995		1996	
	Gross weight	TiO2 content	Gross weight	TiO2 content
Concentrates: 2/				
Ilmenite and titanium slag	201,000	137,000	353,000	267,000
Rutile	54,700	52,300	85,100	77,100
Titanium pigment 3/	120,000	113,000 e/	107,000	100,000 e/

e/ Estimated.

1/ Data are rounded to three significant digits.

2/ Consumer stocks.

3/ Data from Bureau of the Census. Producer stocks only.

TABLE 10
YEAREND PUBLISHED PRICES OF TITANIUM CONCENTRATES AND PRODUCTS

		1995	1996
Concentrates:			
Ilmenite, f.o.b. Australian ports	per metric ton	$81.00-$85.00	$82.00-$92.00
Rutile, bagged, f.o.b. Australian ports	do.	650.00-800.00	700.00-800.00
Rutile, bulk, f.o.b. Australian ports	do.	550.00-650.00	525.00-600.00
Titanium slag, 80% TiO2, Canada e/	do.	244.00	292.00
Titanium slag, 85% TiO2, South Africa e/	do.	349.00	353.00
Metal:			
Sponge	per pound	4.25- 4.50	4.25- 4.50
Ferrotitanium	do.	1.73- 1.76	1.68- 1.75
Scrap; turnings, unprocessed	do.	0.90- 0.95	0.85- 0.90
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do.	.92- .96	1.06- 1.08
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do.	.99- 1.03	1.08- 1.10

e/ Estimated.

Sources: American Metal Market, American Paint and Coatings Journal, Chemical Market Reporter, Industrial Minerals (London), Metal Bulletin, Platt's Metals Week, and industry contacts.

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TABLE 11
U.S. EXPORTS OF TITANIUM PRODUCTS, BY CLASS 1/

Class	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Metal:				
Sponge	255	$1,090	528	$2,820
Scrap	3,420	9,120	3,410	9,050
Other unwrought:				
Billet	343	5,740	489	11,300
Blooms and sheet bars	1,130	25,500	3,060	59,300
Ingot	483	7,860	269	4,520
Other	603	7,370	471	9,140
Wrought:				
Bars and rods	2,030	45,700	1,400	46,100
Other	2,560	117,000	3,130	157,000
Total	10,800	219,000	12,800	299,000
Ores and concentrates	32,300	12,000	15,500	5,890
Pigment and oxides:				
Titanium dioxide pigments	306,000	524,000	292,000	499,000
Titanium oxides	36,000	65,600	40,600	73,800
Total	342,000	589,000	332,000	572,000

1/ Data are rounded to three significant digits, may not add to totals shown.

Source: Bureau of the Census.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATES, BY COUNTRY 1/

Concentrate and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Ilmenite:				
Australia	294,000	$19,100	359,000	$23,200
India	62,100	9,660	114,000	8,390
Other	117,000	5,300	45,300	3,050
Total	473,000	34,000	518,000	34,600
Titanium slag:				
Canada	41,200	11,300	11,500	3,370
South Africa	347,000	121,000	410,000	146,000
Total	388,000	132,000	421,000	149,000
Rutile, natural:				
Australia	61,700	25,200	46,000	18,700
Sierra Leone	10,600	4,040	--	--
South Africa	114,000	41,600	135,000	52,100
Other	5,460	2,780	1,180	961
Total	192,000	73,600	182,000	71,800
Rutile, synthetic:				
Australia	122,000	53,900	108,000	41,200
Malaysia	4,940	2,960	6,850	3,850
Other	43	26	27,200	1,640
Total	127,000	56,900	142,000	46,700
Titaniferous iron ore: 2/				
Canada	88,400	5,200	90,200	7,920

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregated and steel-furnace flux.

Source: Bureau of the Census. Data adjusted by the U.S. Geological Survey.

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TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY 1/

Class and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Unwrought:				
Sponge:				
China	478	$2,860	833	$5,790
Japan	1,140	9,100	4,400	36,000
Russia	5,490	21,200	3,570	21,200
United Kingdom	37	205	71	502
Other	415	1,770	1,230	7,370
Total	7,560	35,200	10,100	70,800
Waste and scrap:				
Canada	368	1,050	408	1,400
France	364	1,370	847	4,650
Germany	613	2,720	559	3,000
Japan	1,830	6,540	2,620	11,600
Russia	3,800	15,600	5,490	32,000
United Kingdom	2,350	9,480	3,770	18,400
Other	1,780	6,700 r/	2,680	11,000
Total	11,100	43,500	16,400	82,100
Ingot and billets:				
Russia	918	6,150	1,550	17,200
United Kingdom	622	7,040	635	9,910
Other	342	5,950	409	7,750
Total	1,880	19,100	2,590	34,800
Powder	238	1,720	240	3,180
Other: 2/				
Russia	430	2,870	289	3,370
Other	511 r/	1,190 r/	66	260
Total	941	4,070	355	3,790
Wrought products and castings: 3/				
Japan	515 r/	15,700 r/	306	13,900
Russia	1,010 r/	10,900 r/	4,730	51,200
United Kingdom	468 r/	8,900 r/	564	14,900
Other	320	9,230 r/	545	15,300
Total	2,310 r/	44,700 r/	6,140	95,300

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes blooms, sheet, bars, slabs, and other unwrought.
3/ Includes bars, castings, foil, pipes, plates, profiles, rods, sheet, strip, tubes, wire, and other.

Source: Bureau of the Census.

TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENTS, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
80% or more titanium dioxide:				
Belgium	792	$1,230	1,020	$1,640
Canada	61,600	102,000	64,900	103,000
China	3,620	3,820	771	961
Finland	2,430	4,900	966	1,970
France	5,560	9,840	2,830	4,920
Germany	21,300	45,700	14,500	34,000
Japan	6,000	13,900	4,210	10,600
Norway	4,400	6,690	5,410	8,540
Singapore	4,450	7,020	4,340	6,990
United Kingdom	1,680	2,770	202	369
Other	8,950	14,200	5,010	8,050
Total	121,000	212,000	104,000	181,000
Other titanium dioxide:				
Canada	17,000	27,800	989	1,970
France	8,120	13,000	9,780	12,900
Germany	1,260	7,140	1,330	10,100
South Africa	6,280	9,760	5,790	7,900
Spain	1,250	2,390	13,900	18,000
United Kingdom	3,300	5,890	3,540	7,120

See footnotes at end of table.

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TABLE 14--Continued
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENTS, BY COUNTRY 1/

Country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Other titanium dioxide--Continued:				
Other	3,180	$7,920	4,100	$7,750
Total	40,400	73,900	39,400	65,700
Titanium oxide:				
Belgium	2,610	4,060	2,290	3,470
Canada	8,560	13,700	2,930	4,920
France	6,740	9,550	5,230	7,520
Germany	654	1,160	8,230	15,100
Norway	68	131	19	30
Other	3,210	9,410	4,800	12,200
Total	21,800	38,000	23,500	43,200
Grand total	183,000	323,000	167,000	290,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 15
TITANIUM: WORLD PRODUCTION OF CONCENTRATES (ILMENITE, LEUCOXENE, RUTILE AND TITANIFEROUS SLAG), BY COUNTRY 1/ 2/

(Metric tons)

Concentrate type and country	1992	1993	1994	1995	1996 e/
Ilmenite and leucoxene: 3/					
Australia:					
Ilmenite	1,786,000	1,804,000	1,782,000	1,980,000 r/	2,028,000 4/
Leucoxene	20,000	21,000	35,000	31,000	30,000 4/
Brazil 5/	76,558	90,567	97,439	102,125	105,000
China e/	150,000	155,000	155,000	160,000	165,000
India e/	300,000	320,000	300,000	300,000	300,000
Malaysia	337,744	288,950	115,885	151,680	244,642 4/
Norway	708,000	713,000	826,000	833,000 r/	750,000
Portugal e/	30	25	20	--	--
Sierra Leone	60,331	62,900	47,400	-- e/	--
Sri Lanka	33,283	76,930	60,445	49,655 r/	62,810 4/
Thailand	2,967	20,821	1,677	33	--
Ukraine	450,000 r/	450,000 r/ e/	530,000 r/	359,000 r/	300,000
United States	W	W	W	W	W
Total	3,920,000 r/	4,000,000 r/	3,950,000 r/	3,970,000 r/	3,990,000
Rutile:					
Australia	183,000	186,000	233,000	195,000 r/	180,000 4/
Brazil	1,798	1,744	1,911	1,985 r/	2,000
India e/	10,000	13,900	14,000	14,000	14,000
Sierra Leone	148,990	152,000	137,000	-- e/	--
South Africa e/	84,000	85,000	78,000	90,000	115,000
Sri Lanka	2,741	2,643	2,410	2,697 r/	3,532 4/
Thailand	281	87	49	--	--
Ukraine	60,000 r/	60,000 r/ e/	80,000 r/	112,000 r/	100,000
United States	W	W	W	W	W
Total	491,000 r/	501,000 r/	546,000 r/	416,000 r/	415,000
Titaniferous slag: 6/					
Canada 7/	753,000	653,000	764,000	815,000 e/	950,000
South Africa 8/ 9/	884,000	892,000	744,000 e/	990,000 e/	990,000
Total	1,640,000	1,550,000	1,510,000	1,810,000	1,940,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through July 22, 1997.

3/ Ilmenite is also produced in Canada and South Africa, but this output is not included here because an estimated 90% of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

4/ Reported figure.

5/ Excludes production of unbeneficiated anatase ore.

6/ Slag is also produced in Norway but is not included under "Titaniferous slag" to avoid duplicative reporting. Beginning in 1990, about 25% of Norway's ilmenite production was used to produce slag containing 75% TiO_2.

7/ TiO_2 content in 1992-96 is not reported.

8/ Contains 85% TiO_2.

9/ Excludes 42,000 to 48,000 metric tons of titanium slag from Highveld Steel.

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TUNGSTEN

By Earle B. Amey and Kim B. Shedd

Tungsten's unique high-temperature properties are beneficial in the production of numerous end-use items. The high melting point, high density, good corrosion resistance, good thermal and electrical conductivity of tungsten and its alloys, and the excellent cutting and wear-resistant properties of its carbides continued to provide important items for consumption in the domestic and military sectors.

Total reported domestic consumption of tungsten in primary end-use categories decreased by about 14% in 1996 compared with that of 1995. Demand generally decreased in the cemented carbide end-use sectors that included the combined cutting tool, mining tool, oil drilling equipment, and wear-resistant component industries. In addition, demand for mill products made from metal powder significantly decreased. Counter to these decreases was a increase in the demand for directly reusable tungsten scrap owing to more tungsten scrap being specified into alloys. Tungsten consumption was healthy because the U.S. economy remained strong, but was not at the record levels of late 1994—early 1995.

During 1996, prices for tungsten concentrates, which had built up in the second half of 1994, weakened. A major liquidation of stockpiles of tungsten ore in Russia and Kazakstan occurred; however, the perception was that there were plenty of concentrates available for conversion to ammonium paratungstate (APT) (Ryan's Notes, 1997b). Because of the uncertainty of the tungsten market, Western mine operators continued to leave their mines on care-and-maintenance status or to keep the mines closed.

The pattern of imports of tungsten materials by U.S. processors during the year showed an increase in APT and unwrought tungsten. China continued to be the dominant supplier of tungsten materials to the United States, providing about 36% of all imported tungsten materials. Competition continued to come from the Russians, but at a lesser degree.

A summary of the important U.S. and international statistics for 1996 and the previous 4 years are shown in table 1.

Tungsten concentrate is sold in units of tungsten trioxide (WO_3). In the United States, sales are in short ton units of WO_3. A short ton unit is 1% of a short ton (20 pounds). Tungsten trioxide is 79.3% tungsten. Therefore, a short ton unit of WO_3 equals 20 pounds of WO_3 and contains 7.19 kilograms (15.86 pounds) of tungsten. In most other countries, tungsten concentrates are sold in metric ton units. A metric ton unit is 1% of a metric ton (10 kilograms). A metric ton unit of WO_3 contains 7.93 kilograms (17.48 pounds) of tungsten.

Legislation and Government Programs

The Defense Logistics Agency (DLA) proposed to sell its entire inventory of tungsten through the year 2005. This U.S. Defense Department Agency sent the legislation that called for proposals to Congress on April 16. DLA would conduct sales of a specified amount per year which would be subject to a Congressional mandate not to disrupt markets (Platt's Metals Week, 1996c). Congress, however, voted in August to eliminate tungsten from the list of materials authorized for disposal in the final proposal (American Metal Market, 1996b). Forms of tungsten in the U.S. National Defense Stockpile included: tungsten ore and concentrates, metal, carbides, and ferrotungsten.

Production

Domestic production data for tungsten were developed by the U.S. Geological Survey by means of two separate, voluntary surveys. These surveys are entitled "Tungsten Ore and Concentrate" and "Tungsten Concentrate and Tungsten Products." Of the 15 mining and 14 processing operations to which survey requests were sent, response was received from 53% and 100%, respectively, of those operations surveyed. Production and stock totals for the survey respondents are shown in table 1.

No tungsten mining activity occurred in the United States in 1996, as the uncertainties in the tungsten market continued. Avocet Mining PLC (Avocet), London, United Kingdom, modernized its conversion facility in Bishop, CA, with some equipment upgrades and processed tungsten ores from Avocet mines in Peru and Portugal, as well as imported feed from the Commonwealth of Independent States (CIS). This facility has an annual APT design capacity of 4,100 metric tons of contained tungsten but is not operating at capacity. Avocet sold approximately 355,000 metric tons units of tungsten trioxide in various concentrate and intermediate forms during 1996. This was equivalent to about 12% of the market outside Russia and China. About 34% of Avocet's sales were produced from the company's tungsten mines and the remainder was obtained from inventory drawdown or bought from third parties (Avocet Mining PLC, 1997).

Major processors of tungsten materials in 1996 were Avocet Tungsten Inc., Bishop, CA; Buffalo Tungsten Inc., Depew, NY; General Electric Co., Euclid, OH; Osram Sylvania, Inc. (formerly GTE Products Corp.), Towanda, PA; Kennametal Inc., Latrobe, PA, and Fallon, NV; and Teledyne Advanced Materials (formerly Teledyne Wah Chang Huntsville),

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Huntsville, AL. Net production statistics for tungsten metal powders, carbides, and chemicals are shown in table 2.

Consumption

Total reported domestic consumption of tungsten in primary end-use categories (table 3) decreased by almost 14% in 1996 compared with that of 1995. Demand generally decreased in the cemented carbide end-use sectors that included the combined cutting tool, mining tool, oil drilling equipment, and wear-resistant component industries. In addition, demand for mill products made from metal powders; ferrotungsten used in steels that included the tool, alloy, and stainless steel sectors; and tungsten chemicals significantly decreased.

Counter to these decreases was an increase in the demand for directly reusable tungsten scrap owing to more tungsten scrap being specified into alloys. Consumption of obsolete tungsten scrap, reprocessed either chemically or physically for reuse, increased to 2,560 metric tons of contained tungsten in 1996 from 2,380 tons in 1995. When tungsten prices increased as they did in the first half of 1995, tungsten scrap became more available. Generally, this scrap was in the form of tungsten carbide cutting tools, drill bits, circuit bed drills, and rollers.

Demand for cemented carbide components in the oil drilling industry fluctuated. The number of operating oil drilling rigs in the United States rapidly declined from a high of 745 in early January to a yearly low of 693 rigs in mid-March and then gradually increased to a yearly high of 861 rigs by yearend, according to figures reported weekly in American Metal Market by the International Association of Drilling Contractors and Baker Hughes Inc.

Prices

The average Metal Bulletin (London) combined price for wolframite and scheelite concentrates, instituted in April 1992, decreased about 18% in 1996 compared with that of 1995. The concentrate price decreased to an average of $52.53 per metric ton unit tungsten oxide from an average of $63.80 per metric ton unit in 1995. This trend for 1996 reversed the upward trend that started in 1994.

In order to facilitate the availability of tungsten scrap in the United States, when tungsten prices increased as they did in the first half of 1995, tungsten scrap market prices follow after a typical time lag of 7 to 12 months. Scrap containing 80% or more tungsten is the most sensitive to price fluctuations. Generally, this scrap is in the form of tungsten carbide cutting tools, drill bits, circuit bed drills, and rollers. An estimated 40% to 50% of all tungsten consumed in the United States is in the form of tungsten scrap (Metal Bulletin, 1996a).

World market prices for APT decreased during 1996, consistent with the decreasing prices for concentrates. According to quotations in Metal Bulletin (London), the average price for APT on the U.S. market, duty-paid and delivered to processing plants, decreased 9% from an average of $75.75 per metric ton unit in January to an average of $68.95 per metric ton unit by yearend. Similarly, quotations for Chinese No. 1 Grade APT in Hong Kong decreased 18% during the year from an average price of $76 per metric ton unit to an average of $62 per metric ton unit. The average price of APT on the European free market decreased 22%, from $78 to $61 per metric ton unit, according to quotations published in Metal Bulletin (London). The actual lowest APT prices per metric ton unit reached during 1996 were $66.22 on the U.S. market (February 8, 1996), $53.50 on the Hong Kong market (September 25, 1996), and $56 on the European free market (November 1, 1996). Mine executives at the Seventh International Tungsten Symposium said APT prices would need to climb above $100 per metric ton unit and that tungsten concentrate would need to stay above $80 per metric ton unit to prove economically viable to revive the more than 10,000 tons of annual capacity lost during the past 15 years (American Metal Market, 1996c).

Foreign Trade

Comprehensive lists of U.S. export and import trade statistics by material, quantity, value and by country of destination and origin are shown in tables 5 through 13.

The pattern of imports of tungsten materials by U.S. processors during 1996 showed an increase in the amount of the intermediate ammonium paratungstate. Concentrate prices decreased during this period with a decrease in demand and the appearance of a depletion of Chinese inventories. In 1996, concentrate represented a 50% share of the combined imports of concentrate and intermediates from all sources compared with a 52% share in 1995, a 44% share in 1994, a 36% share in 1993, a 63% share in 1992, a 67% share in 1991, and an 87% share in 1990, prior to the imposition of an antidumping tariff late in 1991. The share of these combined imports of concentrate and intermediate materials provided by China as intermediate materials was 44% in 1996, up from 33% in 1995.

Total U.S. imports of all tungsten materials decreased 8% in 1996 compared with those of 1995. China continued to be the dominant supplier, providing about 36% of all imported 1996 tungsten materials. In 1996, China's share of the total quantity of tungsten materials imported by the United States was up 11% compared with that of 1995. The total quantity of tungsten materials imported from China increased from 3,800 tons of contained tungsten in 1995 to 4,200 tons in 1996. Of the total tungsten imports from China, the percentage imported as intermediate products was 87% in 1996, 78% in 1995, less than 72% in 1994, and 74% in 1993 and 1992. Russia continued to be competitive with China as one of the dominant suppliers, providing about 20% of all imported tungsten materials. Major suppliers of concentrates to the United States included Russia (40%), Bolivia (19%), Portugal (12%), and Peru (9%).

World Review

Rated world capacity for mines and mills as of December 31, 1996, was approximately 36,000 tons of contained tungsten. Estimated annual mine production capacity declined by about

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10% in 1996 compared with that of 1995. The situation was made worse by significant growth in private mines in China and by the threat of further stockpile releases in China, Kazakstan, Russia, and the United States. Tungsten prices have fallen to levels well below the operating cost for the majority of mines still operating. As a result, production levels worldwide have fallen sharply, and there has been a halt to development of new mines and reserves.

Annual world production of concentrate is shown by country in table 14 and as a total in table 1.

Canada.—Vancouver-based North American Tungsten agreed to purchase all the assets of Canada Tungsten owned by Aur Resources (Aur) for $5 million Canadian dollars. In December 1996, Aur increased its holdings of Canada Tungsten from 48% to 100%. Canada Tungsten's assets include the CanTung Mine in the Northwest Territories that has been shut down for 10 years, the MacTung property near CanTung, and the Hemerdon Mine in England that has not been in operation since World War II (Ryan's Notes, 1997a). In addition, North American Tungsten has taken over the APT equipment at Bishop, CA, that is currently leased to Avocet. The APT equipment can produce about 30,000 metric ton units annually.

China.—China resumed production in approximately half their major tungsten mines in 1996. Most of their small-sized mines remained closed, however, because of shortages of electrical supply. A Chinese delegation visited some tungsten producers in Russia, Romania, and Ukraine during May 1996 to discuss ways to stabilize international tungsten prices (Platt's Metals Week, 1996b).

Mitsubishi Materials Corp. and China's Tianjin Tool Works established a joint venture to build a new tungsten carbide tool plant in China. This facility will be located in an existing Tianjin Tool Works plant in Tianjin, northern China. Operation began in September 1996; about 50 people were employed; and indexable inserts and carbide solid end mills were produced for local company supplies (American Metal Market, 1996a).

China's traders have stopped quoting prices for tungsten and ferrotungsten and have stopped selling these metals officially in the face of dumping from outside China. The dumping allegedly is mainly from European sources (Platt's Metals Week, 1997).

The Chinese government purchased 3,000 metric tons of fine tungsten concentrate from major state-owned mines for its stockpile. This amount of tungsten concentrate is equivalent to 2 months of output by state-owned mines. The first 2,000 metric tons of tungsten ore have been purchased, and the remaining 1,000 metric tons will be purchased in 1997 (Platt's Metals Week, 1996a)

International Tungsten Industry Association (ITIA).—ITIA held its Seventh International Tungsten Symposium in Goslar, Germany, September 24-27, 1996. For the first time, all industries that are involved with tungsten, from mining to end-users, were included. The subjects of the talks reflected the needs of raw material producers as well as companies that use tungsten in their end products. Speakers from 12 countries presented a wide range of papers that focused on all sectors of the tungsten industry—from ores and concentrates, raw materials and powders, hardmetals and heavy metals to traditional uses like lamp wire and modern areas of application, such as welding technology, electronics, chemical production, and medical technology. In addition to the technical content of the symposium, the program offered tours of H.C. Starck GmbH & Co. KG's main plant and headquarters in Goslar and of the Volkswagen plants in Braunschweig and Wolfsburg. One of the highlights was the final session on the tungsten market where Japanese, Eastern and Western European, Russian, Chinese, and United States points of view were presented.

Russia.—Principal Russian mines resumed intermittent production of tungsten during 1995 after being at a standstill for most of 1994. Lermontov Mine (in Primorsky Kray) produced 3,000 tons of tungsten concentrate in the first 9 months of 1995 and only 1,000 tons of tungsten concentrate in the first 6 months of 1996 before stopping production (Platt's Metals Week, 1996d); Primorsky-Gok Mine (also in Primorsky Kray) operated for about one-half of 1995; and Tyrny-Auz Mine (in the Caucasus) operated intermittently. Tyrny-Auz abandoned their open pit operations and produced at a very low level late in 1996 from their underground mines. Some resumption in tungsten production had also taken place in 1996 from Dzinsky Mine at Dzida in the Lake Baikal region and from Kazakstan (Engineering & Mining Journal, 1996).

Most of Russia's tungsten mines closed in 1996 and will be unable to reopen until tungsten prices are higher. On the other hand, most of Russia's stockpile sales have been uncontrolled, and tungsten material has been sold at lower and lower price levels. Hence, Russia's mines have found themselves in competition with their own state stockpile (Metal Bulletin, 1996b).

Current Research and Technology

A nickel-base superalloy is being developed that can reportedly be used as the matrix material for tungsten wire-reinforcement metal matrix composites. This modified chemical composition is formulated to retard interfacial interdiffusion between the tungsten wire and the matrix. As a result, the composite can operate at temperatures up to 2,000° F for applications such as advanced gas turbine engines (Advanced Materials & Processes, 1996a).

A cold-forming technology was recently described at the 1996 World Congress on Powder Metallurgy and Particulate Materials in Washington, DC. The technology uses a patented, one step technique to coat copper onto tungsten powder at ambient temperature. The powders are then pressed to net shape and 100% density to meet the need for a high-temperature, heat-spreading material. This cold-forming process imparts very close tolerances and 100% density without sintering (Advanced Materials & Processes, 1996b).

Tool steels reinforced with tungsten carbide particles have been developed to provide improved thermal fatigue performance and wear resistance. Materials are produced by the hot isostatic pressing of powders of tungsten carbide, carbon, and tool steel. These tool-steel composites have been

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successfully applied in steel mill hot-working rolls, leaf spring hot-work rolls, and aluminum diecasting. The composite may also be clad to the surface of industrial rolls, tools, and dies (Advanced Materials & Processes, 1996c).

Outlook

Based on the first quarter consumption of all tungsten products, the total annual demand for tungsten materials in the United States in 1997 was estimated to be about 6,550 tons of contained tungsten. This would represent about 13% less consumption than the 7,530 tons reported for 1996. The economic recovery rate in 1997 is expected to continue with the substantial gains the economy experienced in 1996. As a result, overall demand for cutting and wear-resistant components integrally associated with the metalworking, machining, construction, transportation, mining, and oil and gas drilling industries is expected to remain high in 1997. In particular, the consumption of cemented carbide tool bit inserts is expected to continue to be strong as the automobile market grows and the requirement for machined automobile parts correspondingly rises. In the short term, demand for tungsten in the lighting, electrical, and electronic sectors is expected to continue to increase slowly; although there could be a significant erosion of this demand should the recent breakthroughs in the development of tungsten-free light bulbs begin to capture a significant portion of the lighting market. The general rate of growth in tungsten demand continued to be dampened by the effects of substitution in the cutting and wear-resistant component industries as well as by technological improvements within the industry that result in more efficient use of tungsten.

The sources of future supplies of tungsten concentrate and intermediate materials for U.S. consumption became even less certain by the end of 1996 as observers indicated that further clearing of inventories by traders had taken place. There is a definite slowdown in the release of tungsten from CIS stockpiles, but is believed to be just a temporary lull (Ryan's Notes, 1997b).

China remained the principal supplier of tungsten products to the world market during 1996; however, many observers believed that stocks of Chinese concentrate have been depleted. A number of Chinese mines were reported as almost exhausted, low in grade, and high in cost to operate. As a result, several of these mines have recently closed, and other mines are expected to follow over the next 10 years. On the other hand, the quantity of tungsten materials available from Russia and certain other members of the CIS continued to be competitive with China. Uncertainties remained regarding the extent to which the CIS might be a source of tungsten supply to the world market as it makes the transition to a market economy. Given all of these tungsten market factors, tungsten sellers maintain that the supply side is tightening at the same time that demand is building and consumer ore stocks are low (Ryan's Notes, 1997b).

Specifically, the future supply of APT from China, the predominant world provider, will continue because of the country's cash needs (Ryan's Notes, 1997b). In addition, China has exhausted its supply of concentrate stocks. Hence, in the short term, the tungsten market is beginning to correct the transition from an oversupply of tungsten to a more closely balanced supply and demand, effectively allowing for the entrance of more producers into the market.

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TABLE 1
SALIENT TUNGSTEN STATISTICS 1/

(Metric tons of tungsten content unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Concentrate:						
Mine production		W	W	W	W	W
Mine shipments		W	W	W	W	W
Value	thousands	W	W	W	W	W
Consumption		4,310	2,870 2/	3,630 2/	6,320	5,420
Exports		38	63	44	20 r/	72
Imports for consumption		2,480	1,720	2,960	4,660 r/	4,190
Stocks, Dec. 31:						
Producer		44	44	44	44	44
Consumer		702	592	756	631	569
Ammonium paratungstate:						
Production		5,760	4,730 3/	536 4/	2,580 5/	4,450 6/
Consumption		7,010	6,970	7,080	7,920 r/	7,800
Stocks, Dec. 31: Producer and consumer		333	420	82	727 r/	558
Primary products:						
Net production		8,450	9,410	7,410	8,410 r/	7,810
Consumption		6,910	7,580	8,110	8,800 r/	7,530
Stocks, Dec. 31:						
Producer 7/		1,510	1,480	1,160	1,300 r/	1,400
Consumer		601	716	849	547	399
World:						
Concentrate:						
Production		42,900 r/	34,400 r/	34,300 r/	38,500 r/	31,900 e/
Consumption 8/		36,500	31,900	31,600	31,000 e/	(9/)

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits.

2/ Excludes 3 months of "Withheld" data.

3/ Excludes 2 months of "Withheld" data.

4/ Excludes 11 months of "Withheld" data.

5/ Excludes 7 months of "Withheld" data.

6/ Excludes 4 months of "Withheld" data.

7/ Excludes cast and crystalline tungsten carbide powder.

8/ Based on data received from United Nations Conference on Trade and Development, Jan. 1996.

9/ The United Nations is no longer collecting and publishing this information.

TABLE 2
NET PRODUCTION 1/ AND STOCKS OF TUNGSTEN PRODUCTS IN THE UNITED STATES 2/

(Metric tons of tungsten content)

	Hydrogen reduced metal powder	Tungsten carbide powder		Chemicals	Total
		Made from metal powder	Cast and crystalline		
Net production 1996	3,720	4,090	W	W	7,810
Net production 1995	2,910	5,500 r/	W	W	8,410 r/
Producer stocks, Dec. 31, 1996	867	406	W	131	1,400
Producer stocks, Dec. 31, 1995	818	357 r/	W	126	1,300 r/

r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Gross production less quantity used to make other products in table.

2/ Data are rounded to three significant digits; may not add to totals shown.

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TABLE 3
REPORTED CONSUMPTION AND STOCKS OF TUNGSTEN PRODUCTS
IN THE UNITED STATES IN 1996, BY END USE 1/

(Metric tons of tungsten content)

End use	Ferro-tungsten	Tungsten metal powder	Tungsten carbide powder	Tungsten scrap 2/	Other tungsten materials 3/	Total
Steel:						
Stainless and heat-resisting	W	--	--	W	2	2
Alloy	33	--	--	--	--	33
Tool	434	--	--	--	W	434
Superalloys	W	W	W	W	W	W
Alloys (excludes steels and superalloys):						
Cutting and wear-resistant materials	--	W	W	W	W	W
Other alloys 4/	W	W	W	W	--	W
Mill products made from metal powder	--	551	--	--	--	551
Chemical and ceramic uses	--	--	--	--	90	90
Miscellaneous and unspecified	55	158	5,760	415	32	6,420
Total	522	709	5,760 5/	415	123	7,530
Consumer stocks, Dec. 31, 1996	27 6/	36	298 5/	24	14	399

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Does not include that used in making primary tungsten products.

3/ Includes tungsten chemicals and others.

4/ Includes welding and hard-facing rods and materials and nonferrous alloys.

5/ Based on reported consumption plus information from secondary sources on companies not canvassed; includes estimates.

6/ Includes scheelite, natural and synthetic.

TABLE 4
MONTHLY PRICE QUOTATIONS OF TUNGSTEN CONCENTRATE IN 1996

	Metal Bulletin (London), European market, 65% WO3 basis, c.i.f. 1/				Metals Week, U.S. spot quotations, 65% WO3 basis, c.i.f. U.S. ports, including duty 2/			
	Dollars per metric ton unit			Dollars per short ton unit,	Dollars per short ton unit			Dollars per metric ton unit,
Month	Low	High	Average	average	Low	High	Average	average
January	50.00	62.00	56.00	50.80	55.00	65.00	60.00	66.14
February	50.00	58.00	54.00	48.99	55.00	65.00	60.00	66.14
March	50.00	62.00	56.00	50.80	55.00	65.00	60.00	66.14
April	52.00	62.00	57.00	51.71	55.00	65.00	60.00	66.14
May	52.00	62.00	57.00	51.71	55.00	65.00	60.00	66.14
June	52.00	62.00	57.00	51.71	55.00	65.00	60.00	66.14
July	45.00	62.00	53.50	48.53	55.00	65.00	60.00	66.14
August	45.00	55.00	50.00	45.36	55.00	65.00	60.00	66.14
September	45.00	55.00	50.00	45.36	55.00	65.00	60.00	66.14
October	40.00	55.00	47.50	43.09	55.00	65.00	60.00	66.14
November	40.00	50.00	45.00	40.82	55.00	65.00	60.00	66.14
December	43.00	53.00	48.00	43.54	55.00	65.00	60.00	66.14

1/ Combined wolframite and scheelite quotations. Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average annual price per metric ton unit of WO3 of all semiweekly low and high prices was $52.53 for 1996. The average equivalent price per short ton unit of WO3 was $47.65 for 1996.

2/ Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average annual price per short ton unit of WO3 of all weekly low and high prices was $60.00 for 1996. The average equivalent price per metric ton unit of WO3 was $66.14 for 1996.

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TABLE 5
U.S. EXPORTS OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY

Country	1995 Tungsten content 1/ (metric tons)	1995 Value (thousands)	1996 Tungsten content 2/ (metric tons)	1996 Value (thousands)
China	--	--	57	$428
Germany	19 r/	$151 r/	1	4
Hong Kong	--	--	1	7
Ireland	--	--	(3/)	3
Japan	--	--	3	26
Mexico	1 r/	5 r/	(3/)	3
Netherlands	--	--	5	38
Singapore	--	--	1	6
United Kingdom	(3/)	3 r/	3	24
Total	20 r/	159 r/	72	539

r/ Revised.
1/ Calculated based upon an estimated value of $62 per metric ton unit WO3.
2/ Calculated based upon an estimated value of $59 per metric ton unit WO3.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 6
U.S. EXPORTS OF AMMONIUM PARATUNGSTATE, BY COUNTRY 1/

Country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Belgium	52	$659	81	$970
Germany	--	--	4	33
Japan	129	1,710	65	303
Korea, Republic of	7	58	--	--
Netherlands	50	331	--	--
Venezuela	--	--	(2/)	3
Total	238	2,760	150	1,310

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 7
U.S. EXPORTS OF TUNGSTEN CARBIDE POWDER, BY COUNTRY 1/

Country	1995		1996	
	Tungsten content (metric tons)	Value (thousands)	Tungsten content (metric tons)	Value (thousands)
Argentina	(2/)	$20	(2/)	$3
Australia	12	616	9	546
Austria	99	1,590	39	749
Belgium	4	209	4	199
Brazil	12	271	4	111
Canada	387	9,990	372	8,940
Chile	(2/)	30 r/	2	86
China	--	--	1	15
Denmark	53	716	4	138
Ecuador	--	--	(2/)	11
Finland	(2/)	5	1	98
France	53	1,370	38	655
Germany	288	5,330	318	5,100
Hong Kong	(2/)	8	1	28
India	1	90	(2/)	3
Ireland	14	153	3	227
Israel	11	734	18	678
Italy	128	4,230	106	3,680
Japan	52	1,280	29	833
Korea, Republic of	4	432	9	597
Luxembourg	5	136	16	498
Mexico	2	76	7	308
Netherlands	97	1,500	12	238
New Zealand	(2/)	14	11	23
Portugal	4	182	4	97
Saudi Arabia	2	82	(2/)	5
Singapore	2	138	9	348
South Africa	63	931	28	426
Sweden	84	1,880	107	4,150
Switzerland	7	608	4	523
Taiwan	25	883	24	994
Thailand	11	89	(2/)	62
Turkey	1	47	1	43
United Arab Emirates	1	50	1	34
United Kingdom	237	3,100	107	1,260
Venezuela	5	199	3	122
Other	(2/) r/	22 r/	2	135
Total	1,660	37,000	1,290	32,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 8
U.S. EXPORTS OF TUNGSTEN AND TUNGSTEN ALLOY POWDER, BY COUNTRY 1/

Country	1995 Gross weight (metric tons)	1995 Tungsten content 2/ (metric tons)	1995 Value (thousands)	1996 Gross weight (metric tons)	1996 Tungsten content 2/ (metric tons)	1996 Value (thousands)
Argentina	--	--	--	2	2	$54
Australia	4	3	$70	2	1	50
Austria	7	5	136	(3/)	(3/)	8
Belgium	2	1	80	(3/)	(3/)	5
Brazil	11	9	334	3	3	212
Canada	49	39	1,210	48	38	1,330
China	(3/)	(3/)	8	10	8	143
Finland	5	4	47	--	--	--
France	18	14	421	6	5	209
Germany	245	196	6,070	91	72	2,350
Honduras	--	--	--	23	18	70
Hong Kong	--	--	--	2	1	54
India	--	--	--	1	1	33
Israel	17	13	113	36	29	159
Italy	44	35 r/	219	2	1	112
Japan	19	15	96	5	4	184
Korea, Republic of	4	3	113	4	3	151
Mexico	9	7	255	7	5	191
Netherlands	42	33	524	2	2	11
Singapore	46	37	821	30	24	538
South Africa	1	1	22	1	1	41
Spain	18	14	52	1	(3/)	16
Sweden	2	1	10	8	6	475
Switzerland	5	4	316	4	3	166
Taiwan	18	14	442	2	1	62
Turkey	--	--	--	1	1	34
United Kingdom	40	32	389	8	6	502
Vietnam	--	--	--	3	2	87
Other	3	3 r/	28 r/	1	1	30
Total	606 r/	485 r/	11,800	300	240	7,280

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Tungsten content estimated by multiplying gross weight by 0.80.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 9
U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country	1995 Tungsten content e/ (metric tons)	1995 Value (thousands)	1996 Tungsten content e/ (metric tons)	1996 Value (thousands)
Tungsten and tungsten alloy wire:				
Argentina	1	$23	(2/)	$18
Belgium	2	195	(2/)	30
Brazil	2	202	1	116
Canada	4	228	9	409
France	1	120	2	305
Germany	(2/)	68	10	435
Guatemala	--	--	1	132
Hong Kong	6 r/	235	3	1,000
India	9	557	14	1,020
Indonesia	1	83	(2/)	26
Italy	1	86	3	277
Japan	6	903	13	1,760
Korea, Republic of	2	140	1	95
Malaysia	2	399	1	306
Mexico	17 r/	1,340	12	1,150
Netherlands	1	62	(2/)	102
Singapore	2	127	(2/)	20
Spain	1	55	6	320
Sweden	1	45	1	144
Switzerland	(2/)	13	(2/)	7
Taiwan	3 r/	233	9	905
United Kingdom	(2/)	167	1	392
Other	1 r/	115 r/	(2/)	85
Total	61 r/	5,400 r/	88	9,050
Unwrought tungsten and alloy in crude form, waste and scrap:				
Australia	70 r/	378	7	74
Brazil	11	70	5	34
Canada	37 r/	308	7	102
Chile	--	--	6	35
France	1 r/	16	8	46
Germany	357 r/	2,320	336	1,850
Israel	4 r/	31	15	88
Italy	28 r/	161	19	128
Japan	53 r/	303	9	60
Mexico	11 r/	97	42	279
Netherlands	13	70	--	--
Spain	24 r/	135	--	--
Sweden	--	--	43	379
Taiwan	--	--	4	21
Ukraine	40	165	--	--
United Kingdom	39 r/	289	45	412
Other	9 r/	60 r/	17	127
Total	697 r/	4,400 r/	565	3,630
Other tungsten metal:				
Australia	1	63	2	171
Belgium	(2/)	5	4	365
Brazil	3	294	3	248
Canada	6	326	6	339
Colombia	(2/)	21	1	64
France	1	114	1	142
Germany	2 r/	1,260	11	855
Hong Kong	4	416	2	144
India	4	226	4	268
Ireland	6 r/	780	(2/)	161
Israel	3	1,060	1	222
Italy	1	85	1	89
Japan	3	858	6	1,460

See footnotes at end of table.

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TABLE 9--Continued
U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country	1995 Tungsten content e/ (metric tons)	1995 Value (thousands)	1996 Tungsten content e/ (metric tons)	1996 Value (thousands)
Other tungsten metal-Continued:				
Korea, Republic of	3	$237	2	$899
Mexico	11 r/	665	13	1,240
Netherlands	1	366	2	315
Singapore	3	714	2	573
South Africa	1	62	1	116
Sweden	(2/)	47	1	100
Switzerland	1	184	1	136
Taiwan	10	847	7	902
Thailand	1	69	1	256
United Kingdom	11 r/	861	13	921
Venezuela	(2/)	47	(2/)	39
Other	1 r/	175 r/	1	129
Total	77 r/	9,780	85	10,200
Ferrotungsten and ferrosilicon tungsten:				
Canada	--	--	2	22
Korea, Republic of	(2/)	7	--	--
Mexico	26 r/	62	--	--
Netherlands	(2/) r/	3	--	--
Total	27 r/	72	2	22
Wrought tungsten:				
Belgium	(2/)	43	1	151
Brazil	2	169	(2/)	11
Canada	31 r/	1,130	19	772
Chile	2	228	1	43
China	(2/)	108	(2/)	82
France	4	545	22	736
Germany	91 r/	2,650	36	975
India	10	595	2	142
Israel	3 r/	263	1	55
Italy	4	370	5	353
Japan	9 r/	1,420	8	1,020
Korea, Republic of	9	453	2	113
Mexico	(2/)	24	3	165
Netherlands	(2/)	40	(2/)	8
Singapore	1	71	1	64
Spain	8 r/	447	6	336
Sweden	2	219	(2/)	28
Taiwan	9	725	6	532
United Kingdom	8	508	2	219
Other	1 r/	94 r/	2	234
Total	193 r/	10,100 r/	113	6,040
Other tungsten compounds: 3/				
Brazil	5	81	(2/)	8
Canada	2	7	2	10
France	2	362	--	--
Netherlands	10	15	11	16
Taiwan	3	5	--	--
United Kingdom	1	24	--	--
Total	23	494	13	34

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes only other tungstates.

Source: Bureau of the Census.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF TUNGSTEN ORE AND CONCENTRATE, BY COUNTRY 1/

Country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Australia	201 r/	$1,280 r/	--	--
Bolivia	499 r/	3,210 r/	782	$4,190
Brazil	11	77	11	69
Burma	61 r/	447 r/	33	190
Canada	1	2	--	--
China	1	15	--	--
Kazakstan	53	272	125	689
Mexico	134 r/	931 r/	166	644
Mongolia	35	166	--	--
Netherlands	126	934	202	1,160
Peru	500 r/	3,450 r/	385	2,450
Portugal	164 r/	1,080 r/	518	3,360
Russia	2,540 r/	11,400 r/	1,690	7,190
Rwanda	--	--	13	65
Singapore	76	469	--	--
Spain	--	--	6	45
Sweden	78	480	--	--
Thailand	98	512	60	361
Uganda	85	522	--	--
United Kingdom	--	--	203	1,080
Total	4,660 r/	25,200 r/	4,190	21,500

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PARATUNGSTATE, BY COUNTRY 1/

Country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Austria	16	$140	--	--
China	987	8,550	1,440	$9,690
Germany	85	1,250	63	524
Hong Kong	113	797	15	69
Japan	--	--	18	124
Netherlands	--	--	1	12
Russia	42	347	--	--
Sweden	50	103	38	193
Switzerland	(2/)	1	--	--
Total	1,290	11,200	1,580	10,600

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

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TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF FERROTUNGSTEN, BY COUNTRY 1/

Country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Austria	27	$130	--	--
China	362	2,160	312	$2,010
Germany	43	213	1	16
Hong Kong	--	--	13	88
Latvia	88	305	--	--
Mexico	21	123	--	--
Russia	82	379	163	993
Sweden	--	--	(2/)	1
United Kingdom	29	160	45	302
Total	652	3,470	535	3,410

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Waste and scrap:				
Australia	7	$31	16	$71
Austria	41	283	33	208
Belgium	21	107	--	--
Canada	35	214	25	175
China	16	101	7	54
Denmark	5	44	3	13
France	63	431	68	322
Germany	635	3,890	272	2,180
Ireland	20	133	32	224
Israel	101	516	48	257
Italy	43	242	22	136
Japan	408	2,480	347	1,860
Korea, Republic of	--	--	63	279
Mexico	15	110	10	55
Netherlands	22	158	48	359
Pakistan	25	78	49	198
Peru	--	--	9	54
Portugal	--	--	1	6
Russia	23	86	289	1,880
Singapore	25	133	57	290
South Africa	75	432	58	293
Sweden	25	177	70	432
Taiwan	--	--	7	48
United Kingdom	492	1,780	310	1,560
Other	15 r/	95 r/	--	--
Total	2,110	11,500	1,840	11,000
Unwrought tungsten, except alloys, in lumps, grains, and powders:				
Belgium	4	175	5	220
Canada	18 r/	437	10	310
China	196	2,520	15	235
Czech Republic	5	81	10	176
France	(2/)	17	23	147
Germany	28	1,200	37	1,450
Japan	36	1,690	27	2,340
Russia	11	227	57	782
South Africa	8	33	--	--

See footnotes at end of table.

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TABLE 13--Continued
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Unwrought tungsten, except alloys, in lumps, grains, and powders--Continued:				
Sweden	--	--	46	$1,600
United Kingdom	(2/)	$5	170	1,530
Other	6 r/	83 r/	5	47
Total	312 r/	6,470 r/	404	8,840
Unwrought tungsten, ingots, shot, alloy, and other: 3/				
Austria	3	118	3	139
Korea, Republic of	--	--	6	32
Russia	(2/)	3	14	100
Switzerland	--	--	2	198
Other	(2/)	8 r/	1	74
Total	3	129	26	543
Wrought tungsten wire, plate, sheet, strip, foil, and other: 3/				
Austria	46 r/	3,650	27	4,490
Belgium	1	100	(2/)	21
Canada	1	68	(2/)	26
China	41 r/	1,660	35	1,620
France	1	166	2	427
Germany	10	1,560	4	709
Hong Kong	4	284	5	369
Hungary	7	748	5	583
Israel	10 r/	538	8	539
Japan	37 r/	7,170	44	7,990
Mexico	6 r/	751	6	936
Netherlands	2	386	3	346
Russia	1	32	2	143
Switzerland	7	960	2	413
United Kingdom	5 r/	664	5	985
Other	1 r/	230 r/	1	189
Total	180 r/	19,000	149	19,800
Calcium tungstate:				
Australia	24	135	--	--
Bolivia	10	43	--	--
China	52	314	53	240
Ireland	--	--	10	20
Japan	1	40	1	88
Total	86	532	65	348
Tungsten oxides:				
Austria	19	170	--	--
China	1,240	12,300	1,530	11,800
Germany	3	69	2	39
Hong Kong	36	272	145	1,010
Russia	822	6,660	152	1,130
United Kingdom	1	27	(2/)	2
Uzbekistan	--	--	30	65
Other	2 r/	20	--	--
Total	2,120	19,600	1,860	14,000
Other metal-bearing materials in chief value of tungsten:				
China	1 r/	32	--	--
Germany	1	55	--	--
Italy	5 r/	168	--	--
Mexico	(2/)	13	--	--
Total	7 r/	268	--	--
Chlorides of tungsten:				
Canada	--	--	(2/)	2
China	--	--	2	13
Russia	(2/)	2	--	--
Total	(2/)	2	2	15
Sodium tungstate:				
Australia	18	108	--	--
Bolivia	28	145	--	--
China	761	5,260	683	4,230

See footnotes at end of table.

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TABLE 13--Continued
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY 1/

Product and country	1995 Tungsten content (metric tons)	1995 Value (thousands)	1996 Tungsten content (metric tons)	1996 Value (thousands)
Sodium tungstate--Continued:				
Germany	10	$266	(2/)	$35
Hong Kong	26	133	28	170
Ireland	1	40	--	--
Japan	(2/)	17	(2/)	4
Malaysia	14	78	--	--
Switzerland	--	--	(2/)	3
Zambia	(4/)	(4/)	--	--
Total	858	6,040	711	4,440
Tungsten carbide:				
Austria	(2/)	31	(2/)	11
Canada	52	1,670	58	1,490
China	149	3,090	134 5/	2,540 5/
France	(2/)	2	(2/)	3
Germany	165	4,550	150	4,740
Hong Kong	--	--	13	404
Israel	13	188	3	50
Japan	13	129	2	274
Korea, Republic of	3	72	(2/)	5
Switzerland	(2/)	4	3	100
United Kingdom	78 r/	541	40	386
Other	2	42 r/	1	54
Total	476	10,300	404	10,100

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Content estimated from reported gross weight.
4/ Revised to zero.
5/ Not included in total is 8 metric tons of material from China with a value of $107,000 with content not yet verified.

Source: Bureau of the Census.

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TABLE 14
TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of tungsten content)

Country	1992	1993	1994	1995	1996 e/
Australia	159	23	11 e/	-- r/	-- 3/
Austria	1,489	104	--	188 r/	360 3/
Bolivia	851	287	462	655 r/	582 3/
Brazil	205	245	155	98 r/	100
Burma 4/	531	524	548	531	328
China e/ 5/	25,000	21,600	27,000	27,400 r/	24,000
India	2	1	2	2	2
Japan	347	66	--	--	--
Kazakstan e/	200	200 r/	200 r/	225 r/	220
Korea, North e/	1,000	1,000	900	900	900
Korea, Republic of	247	200 e/	--	--	--
Malaysia	3 e/	2	--	--	--
Mexico e/	162 3/	-- r/	-- r/	228 r/	149
Mongolia e/	260	250	150	200	200
Peru	543 r/	388 r/	259 r/	728 r/	331 3/
Portugal	1,126 r/	768 r/	100 r/	1,511 r/	1,343 3/
Russia e/	10,000	8,000	4,000	5,400	3,000
Rwanda e/	175	175	30	--	--
Tajikistan e/	200	150	100	75	50
Thailand	70	80	40 r/	60 r/ e/	50
Uganda	16 r/	5 r/	12 r/	17 r/	-- 3/
United States	W	W	W	W	W
Uzbekistan e/	300	300	300	300	300
Total	42,900 r/	34,400 r/	34,300 r/	38,500 r/	31,900

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data through June 9, 1997.

3/ Reported figure.

4/ Includes content of tin-tungsten concentrate.

5/ Based upon data published in the Yearbook of Nonferrous Industry of China, 1993-96.

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VANADIUM

By Henry E. Hilliard

In 1996, vanadium (V) consumption was 4,650 metric tons of contained vanadium. The U.S. supply consisted of vanadium-bearing ferrophosphorus slag, iron slag, fly ash, petroleum residues, and spent catalysts. The United States imported 1,880 tons of ferrovanadium (V-content), 485 tons of vanadium pentoxide anhydride (V-content),and 2,610 tons (V-content) of other vanadium products valued at about $50 million. The United States exported about 3,700 tons of vanadium products valued at about $30 million. Total imports of vanadium materials in 1996 decreased about 5% from imports in 1995. Almost all of the decrease was due to lower vanadium-bearing slag imports from South Africa. The volume of exports of vanadium materials increased by about 41%.

Many uses of vanadium have been developed, including vanadium catalysts, pigments, electronics applications, and titanium-aluminum-vanadium aerospace alloys. About 90% of vanadium demand was for steel products, with titanium-aluminum-vanadium alloys and vanadium chemicals accounting for most of the remainder. Most vanadium is used in the form of ferrovanadium. Ferrovanadium is used as a means of introducing vanadium into steels, where it gives additional strength and toughness. In steels, the use can be subdivided into micro-alloyed or low-alloy steels, which generally contain less than 0.15% vanadium, and high-alloy steels. Ferrovanadium is available in alloys containing 45% to 50% and 80% vanadium. The 80% grade is mostly produced by the aluminothermic reduction of vanadium pentoxide in the presence of steel scrap or by direct reduction in an electric arc furnace. The 45% to 50% grade is produced from slag and other vanadium-containing materials by the silicothermic reduction of vanadium pentoxide. Vanadium addition to titanium alloys is made with aluminum-vanadium master alloys, which are also produced by the aluminothermic reduction of vanadium pentoxide followed by vacuum refining.

Legislation and Government Programs

The Strategic and Critical Materials Stock Piling Act mandates that a stock of strategic and critical materials be maintained to decrease and eliminate, where possible, dependence upon foreign sources of supplies in times of national emergency. The urgency surrounding the security of supply of strategic and critical materials faded away after the collapse of the Soviet Union and the end of the Cold War. The result has been that the U.S. Government stopped acquiring certain materials for the National Defense Stockpile (NDS) and began disposing of what it considered to be excess stockpile inventories. The Defense Logistics Agency (DLA), which has operational control of the NDS, identified vanadium as one of the materials for disposal. DLA cash disposals totaled $427 million in fiscal year 1995 and $391 million in fiscal year 1996. Vanadium pentoxide sales represented only about $3 million of the total. Soon after the Defense Authorization Bill for fiscal year 1996 was signed into law, DLA introduced its Annual Materials Plan (AMP) for fiscal year 1997. The AMP spelled out the maximum allowable quantities of materials that could be sold during the year. Included were 200 short tons of vanadium pentoxide. No other laws directly affecting the stockpile were enacted during the reporting period.

Duty-free status under the Generalized System of Preferences was restored to vanadium pentoxide from South Africa, retroactive to October 1, 1996. A Presidential proclamation on October 17, 1996, included an annex that freed importers of South African V_2O_5 from paying a 13.0% duty on the material. The duty-free status was in effect through May 31, 1997. The change did not have an immediate impact on domestic ferrovanadium producers because most do not rely on South African vanadium pentoxide. However, there are some specialty-alloy producers who depend on imported material that may be affected by restoration of duty free status of vanadium pentoxide from South Africa.

Prices

For most of 1996, the European prices for vanadium pentoxide and ferrovanadium remained fairly stable in the ranges $2.98 to $3.10 per pound and $15.00 to $15.25 per kilogram of vanadium content respectively. Domestic vanadium pentoxide prices began 1996 in the range $2.85 to $3.00 per pound and continued at that level through the first quarter. Prices began to increase somewhat in the second quarter, rising to the $3.05 to $3.15 range by mid-April. Prices remained flat for most of the remainder of the year. Prices started to rise again in November, closing out the year in the $3.28 to $3.35 range. Unlike the price of pentoxide, the price of FeV was flat through the entire year. FeV prices began the year in the $7.35 to $7.45 pound range, fell to $7.20 to $7.40 in July and closed out 1996 at the $7.40 to $7.60 range.

Production

The major marketplace vanadium materials are vanadium pentoxide, ferrovanadium, aluminum-vanadium alloys, vanadium chemicals, and vanadium-bearing iron slags. The United States produced all of these with the exception of vanadium-bearing iron slags.

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Domestic production data for vanadium were developed by the U.S. Geological Survey (USGS) from a voluntary survey of all U.S. operations. All U.S. vanadium pentoxide producers responded to the survey. In addition to the vanadium pentoxide mills, the USGS canvassed three other companies which produce ferrovanadium, vanadium metal, vanadium chemicals, and other specialty vanadium alloys, e.g. aluminum-vanadium master alloys. These three companies also responded to the voluntary survey.

Consumption

Metallurgical applications continued to dominate vanadium use in 1997, accounting for more than 97% of total consumption. Nonmetallurgical applications included catalysts, ceramics, vanadium chemicals, and electronics. The dominant nonmetallurgical use was in catalysts. Much less was consumed for ceramic and electronics (batteries).

Consumption data for vanadium are developed by the USGS from a voluntary survey of all known domestic consumers. There were 61 respondents to the 1996 survey. The 61 respondents represented about 77% of the total canvassed and were estimated to have accounted for about 93% of total consumption, or about 4,325 metric tons. The consumption of nonrespondents, derived by using their past consumption relationships, trends, and data from nonsurvey sources, was estimated to be about 326 tons. The USGS estimate of total reported U.S. consumption of vanadium in 1996 was 4,650 tons as shown in table 1.

World Review

In South Africa, Highveld Steel & Vanadium Corporation's resumption of vanadium pentoxide and ferrovanadium production at its subsidiary, Transvaal Alloys, served notice to the rest of the vanadium industry of its intention to move aggressively into the production of down-stream value-added vanadium products. This development is in line with the trend at other South African producers toward the production of ferrovanadium. Highveld purchased Transvaal in 1994 with the intention of entering the vanadium chemical market. Transvaal's chemical operations were moved to Vanchem, Highveld's chemical division. Transvaal's vanadium mining operations were closed because Highveld did not need the pentoxide and ferrovanadium capacity. The reopening of the Transvaal plant expanded Highveld's FeV capacity from 1,000 to 4,000 tons per year. At about the same time that Highveld restarted FeV production at the Transvaal plant, it reduced sharply its exports of vanadium-bearing slag and began converting most of this material to ferrovanadium, most of which was exported. U.S. imports of ferrovanadium from South Africa increased from none in 1983 to 231 tons in 1996. U.S. imports of South African vanadium pentoxide during this same period increased from 121 to 769 tons. These developments occurred as the availability of V_2O_5 from China for sale on the spot market decreased sharply. China's short supply of raw materials was caused by a shortage of vanadium-bearing slag deliveries from New Zealand to China. Also, Highveld had not shipped slag to China since the first quarter of 1995. The net result has been higher vanadium pentoxide prices. Also, European converters who depended exclusively on South African vanadium-bearing slag have had to scramble to find another source of raw materials.

Current Research and Technology

Vanadium Pentoxide Recovery From Orimulsion Planned.—A German plant that recovers vanadium pentoxide from fly ash was set to open in 1997. The plant at Hennstedt, near the Danish border, will recover 2,000 tons of vanadium pentoxide, 250 tons of nickel, and 14,000 tons of magnesium sulfate per year. The metals will be recovered from ash produced at a powerplant in Denmark that imports 1 to 1.5 million tons per year of Venezuelan Orimulsion. The recovery plant will be owned by a joint venture in which Bitor Energy, which markets Orimulsion, has a 45% stake; Reakt of the United Kingdom will have 10%; and Strategic Minerals Corp. (Stratcor), a U.S. vanadium producer, 45%. There are plans for Britain to import 4 to 5 million tons per year of Orimulsion to be burned at a powerplant in Pembroke, south Wales, contingent on Government approval. Following Government approval, another metals recovery plant might eventually be built at Pembroke. Orimulsion consists of heavy crude oil mixed with 30% water. Venezuela plans to increase production of Orimulsion from 4.8 million tons in 1996 to 20 million tons by 2000 (Financial Times, 1996).

Vanadium Battery Under Development in Japan.—Companies affiliated with Mitsubishi of Japan are undertaking a project to incorporate vanadium secondary batteries into power generation plants by 2000. Kajima-Kita Kyodo Hatsudan, a power generation company, is in charge of the development of the battery. The vanadium secondary battery contains a vanadium pentoxide-sulfuric acid electrolyte and carbon electrodes. At the current state of development, the battery has a capacity of 10 kilowatts (kW). Beginning in October 1996, the Mitsubishi Companies will produce large batteries with a capacity of 200 kW per charge and will market the batteries as power sources in power generation plants, "intelligent" buildings, and related areas.

Small vanadium secondary batteries, with a capacity of 50 kW, are also under development as part of the Japanese Ministry of International Trade and Industry's 'New Sunshine Program.' Kajima-Kita is developing these small models for use as backup power sources for solar batteries. The possibility of using vanadium batteries in electric vehicles is also under investigation.

Kajima-Kita currently extracts vanadium pentoxide from petroleum residues. The company recovered 150 tons in 1994 and 200 tons in 1995 (Roskill's Letter From Japan, 1996).

Vanadium Oxides Toxicities Investigated.—The "in-vivo"-toxicity of vanadium pentoxide and vanadium trioxide (administered orally, dermally and by inhalation) has been

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reinvestigated with particular emphasis on the safety and handleability of vanadium oxides in the vanadium processing industry. Chemical thermodynamic properties of vanadium oxides make it likely that some earlier results of vanadium toxicities have introduced artifacts as a consequence of the administration techniques used. In this investigation, special precautions were taken to avoid any chemical changes or any artificial interactions during sample preparation to ensure that the results significantly reflect the toxicities of vanadium compounds as exposure to them might occur. In the industrial situation the most pertinent results are those from toxicity tests involving oral or inhalative administration. The results of this investigation indicate that, as far as these two parameters are concerned, vanadium pentoxide should be classified as "harmful" according to EEC Directive 83/467/EEC. Vanadium trioxide has a significantly lower toxicity and should be classified as "relatively non-toxic" if swallowed (Monatshefte für Chemie, 1994).

Vanadium Foil Selected For Use in Superconducting Cables.—A process has been proposed for the manufacture of cables that contain the ceramic high-temperature superconductor $YBa_2Cu_3O_{7-\alpha}$. The cables would carry electrical current with little or no loss of power when cooled to about -200°C. The process would begin with the mixing of oxides of yttrium, barium, and copper with water to form a slurry, followed by drying of the slurry, followed by calcining in a rotating kiln to obtain a stoichiometric precursor oxide. In the next few steps, a thin vanadium metal foil would be unspooled and formed into a V-channel, onto which the precursor powder would be metered. The foil is permeable to oxygen at high temperatures (850 to 950°C) to which the cable would be subsequently exposed, but is impervious to oxygen and other environmental contaminants at the lower temperatures at which the cable would be used. Vanadium was selected as the foil material because it exhibits the desired permeability-versus-temperature characteristics, plus a favorable thermal-expansion characteristic (NASA Tech Briefs, 1996).

Vanadium Alloys Under Consideration for Use in Fusion Applications.—Vanadium alloys hold the promise to fully exploit the environmental attractiveness of advanced fusion energy systems. Although a fusion powerplant does not generate fission products, its structural components can become radioactive as a result of nuclear transmutations within the component materials from exposure to neutrons. To fully exploit its environmental attractiveness, fusion energy systems will require low-activation structural materials, which have low levels of induced radioactivity. The U.S. Fusion Materials Program of the Department of Energy's Office of Fusion Energy Science is pursuing the development of low-activation materials, including vanadium alloys, ferritic-martensitic steels, and SiC/SiC composites. Vanadium alloys are under consideration because they have the potential for minimum environmental impact and provide properties superior to those of steels and other candidate materials. For example, vanadium alloys can accommodate high heat loads and can operate at temperatures up to 700 to 750° C (1,300 to 1,380°F). They can provide favorable safety and environmental features, such as low long-term activation, low decay heat and reduced contact dose, low helium and hydrogen generation rates from fusion neutrons, and a potential for recycling. They can be rolled into thin sheets, extruded into tubing, and welded by several methods. Recent investigations have included compositions (in weight-percent) of V, 0-15Cr, 1-20Ti, 0-1Si. Current emphasis is on a reference composition of V, 4Cr, 4Ti, 0.05Si, which appears to have the best combination of properties (Johnson and others, 1997).

Outlook

The vanadium market in the near term will continue to follow the cyclical nature of the steel industry. It is believed that the consumption of vanadium in steel will continue to increase, owing in part to the need for stronger and lighter steels. The demand for vanadium is also expected to increase as new applications are found (see current research and technology section). Promising work on the use of vanadium in new high-strength pipeline steels, thin slab castings, and stainless steels is being pursued. Also, a much talked about vanadium battery may become viable (Roskill's Letter From Japan, 1996). The International Iron and Steel Institute, at its annual conference in October, predicted a growth in apparent world steel consumption in 1997 of 3.4% above consumption in 1996 (Metal Bulletin, 1996). Despite a predicted 1% decline in steel consumption in the United States, an overall world growth is expected which will result in greater demand for vanadium.

The reserve base of vanadium is more than 27 million tons, a sufficiently large supply that will satisfy the market well into the 22d century. This does not take into account increased production of vanadium from spent catalyst, fly ash, and other petroleum residues.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT VANADIUM STATISTICS 1/

(Metric tons of contained vanadium unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium 2/	W	W	W	W	W
Value thousands	W	W	W	W	W
Vanadium oxide recovered from ore 3/	W	W	W	W	W
Vanadium recovered from petroleum residues 4/	1,350	2,870	2,830	1,990	3,730
Consumption	4,080	3,970	4,280	4,650 r/	4,650
Exports:					
Ferrovanadium	213	219	374	340	479
Vanadium pentoxide (anhydride)	26	126	335	229	241
Other oxides and hydroxides of vanadium	1,110	895	1,050	1,010	2,670
Imports for consumption:					
Ferrovanadium	592	1,630	1,910	1,950	1,880
Vanadium pentoxide (anhydride)	206	70	294	547	485
Other oxides and hydroxides of vanadium	103	19	3	36	11
Ore, slag, ash, and residues	838	1,450	1,900	2,530 r/	2,270
World: Production from ore, concentrate, slag 5/	33,200 r/	34,600	34,700	37,700 r/	39,100 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mill, plus vanadium recovered from ferrophosphorus slag derived from domestic phosphate rock.

3/ Produced directly from all domestic ores and ferrophosphorus slag; includes metavanadates.

4/ Includes vanadium recovered from fly ash, petroleum residues, and spent catalysts.

5/ Excludes U.S. production.

TABLE 2
U.S. VANADIUM PENTOXIDE PRODUCERS

Producer	Plant location	Capacity (metric tons pentoxide per year)
AMAX Metals Recovery Inc.	Braithwaite, LA	1,800
Energy Fuels Nuclear Inc.	Blanding, UT	6,800
Gulf Chemical & Metallurgical Corp.	Freeport, TX	1,400
Kerr-McGee Chemical Corp.	Soda Springs, ID	2,000
U.S. Vanadium Corp.	Hot Springs, AR	6,800

TABLE 3
U.S. CONSUMPTION AND CONSUMER STOCKS OF VANADIUM MATERIALS 1/

(Kilograms of contained vanadium)

	1995		1996	
Form	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium 2/	4,320,000 r/	347,000 r/	4,240,000	279,000
Oxide	16,200	7,910	14,600	6,880
Ammonium metavanadate	W	W	W	W
Other 3/	315,000	14,000	394,000	14,700
Total	4,650,000 r/	369,000 r/	4,650,000	301,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes other vanadium-iron-carbon alloys as well as vanadium oxides added directly to steel.

3/ Consists principally of vanadium-aluminum alloy and small quantities of other vanadium alloys and vanadium metal.

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TABLE 4
U.S. CONSUMPTION OF VANADIUM IN 1996, BY END USE 1/

(Kilograms of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,820,000
Stainless and heat resisting	21,700
Full alloy	1,030,000
High-strength low-alloy	890,000
Tool	433,000
Unspecified	W
Total	4,200,000
Cast irons	W
Superalloys	16,000
Alloys (excluding steels and superalloys):	
Cutting and wear-resistant materials	259
Welding and alloy hard-facing rods and materials	3,240
Magnetic alloys	W
Other alloys	386,000
Chemical and ceramic uses:	
Catalysts	W
Pigments	W
Miscellaneous and unspecified	49,700
Grand total	4,650,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
1/ Data are rounded to three significant digits; may not add to total shown.

TABLE 5
U.S. EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

	1995		1996	
Material and country	Quantity	Value	Quantity	Value
Aluminum-vanadium master alloy: 2/ (gross weight)				
Argentina	--	--	1,080	$14,000
Australia	336	$4,360	499	6,380
Austria	71,600	316,000	16,100	178,000
Barbados	--	--	18,900	237,000
Brazil	216	2,810	--	--
Canada	120,000	1,620,000	94,300	1,160,000
Chile	--	--	770	10,000
China	26,300	355,000	--	--
Ecuador	465	12,500	--	--
France	11,200	146,000	2,980	38,800
Germany	11,400	151,000	7,390	110,000
Honduras	5,450	68,800	--	--
India	1,440	18,700	--	--
Ireland	671	10,300	782	14,600
Japan	3,670	65,200	20,400	322,000
Korea, Republic of	6,420	84,200	3,270	42,500
Malaysia	--	--	897	11,700
Mexico	367,000	4,840,000	32,900	434,000
Netherlands	8,550	111,000	--	--
Philippines	535	7,000	409	5,310
Russia	--	--	15,200	274,000
Singapore	7,380	93,700	--	--
Suriname	--	--	139	6,460
Switzerland	--	--	571	7,420
Taiwan	--	--	20,700	291,000
United Kingdom	16,800	281,000	68,700	1,200,000
Venezuela	--	--	3,810	49,600
Total	660,000	8,190,000	310,000	4,410,000

See footnotes at end of table.

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TABLE 5--Continued
U.S. EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

Material and country	1995		1996	
	Quantity	Value	Quantity	Value
Ferrovanadium:				
Australia	--	--	546	$6,830
Canada	225,000	$3,960,000	320,000	5,720,000
Guatemala	--	--	114	3,760
Japan	5,910	137,000	--	--
Mexico	109,000	2,460,000	156,000	3,020,000
Venezuela	--	--	2,300	76,800
Total	340,000	6,550,000	479,000	8,830,000
Vanadium pentoxide (anhydride): 3/				
Australia	839	10,500	--	--
Austria	--	--	19,100	99,400
Belgium	--	--	7,850	103,000
Chile	1,270	12,100	18	2,680
France	1,300	12,300	12,100	132,000
Germany	25,000	290,000	--	--
Italy	26,800	235,000	107,000	913,000
Japan	14,200	121,000	13,800	126,000
Kuwait	--	--	4,970	34,300
Mexico	29,500	314,000	6,370	62,500
Netherlands	95,200	594,000	16,300	116,000
Pakistan	5,170	76,100	6,040	83,600
Peru	--	--	2,260	10,400
Saudi Arabia	4,820	21,600	--	--
Singapore	--	--	962	14,600
Taiwan	21,000	105,000	632	6,000
United Kingdom	3,690	35,000	43,500	356,000
Venezuela	405	4,980	--	--
Total	229,000	1,830,000	241,000	2,060,000
Other oxides and hydroxides of vanadium:				
Argentina	--	--	1,360	7,600
Australia	1,860	16,500	675	6,000
Belgium	15,900	105,000	--	--
Brazil	1,810	3,670	--	--
Canada	810,000	5,430,000	327,000	2,360,000
France	45,000	343,000	15,200	128,000
Germany	61,500	708,000	6,290	67,300
Italy	--	--	17,200	137,000
Japan	37,100	271,000	100	3,610
Mexico	--	--	2,500	25,600
Netherlands	3,630	43,600	--	--
Russia	--	--	12,300	110,000
South Africa	20,000	168,000	61,100	474,000
Spain	--	--	2,210,000	9,030,000
Switzerland	--	--	13,800	74,100
Taiwan	42	5,820	--	--
Venezuela	11,300	101,000	--	--
Total	1,010,000	7,200,000	2,670,000	12,400,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes vanadium metal.
3/ May include catalysts containing vanadium pentoxide.

Source: Bureau of the Census.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

Material and country	1995		1996	
	Quantity	Value	Quantity	Value
Aluminum-vanadium master alloy: (gross weight)				
Germany	36,300	$342,000	1,610	$16,500
Ferrovanadium:				
Austria	113,000	2,030,000	45,100	718,000
Belgium	345,000	6,270,000	62,700	947,000
Canada	724,000	10,200,000	685,000	10,700,000
China	226,000	4,300,000	251,000	3,520,000
Czech Republic	288,000	3,390,000	487,000	6,820,000
Germany	31,000	604,000	2,690	32,300
Korea, Republic of	18,200	363,000	--	--
Russia	160,000	1,950,000	70,400	1,440,000
South Africa	49,700	898,000	231,000	3,490,000
Tajikistan	--	--	40,500	626,000
Total	1,950,000	30,000,000	1,880,000	28,300,000
Vanadium pentoxide (anhydride): 2/				
China	92,500	945,000	27,400	329,000
France	5,830	384,000	9,470	223,000
Germany	4,790	23,400	494	21,700
Hong Kong	--	--	1,330	37,500
South Africa	444,000	5,690,000	446,000	5,540,000
Total	547,000	7,040,000	485,000	6,150,000
Other oxides and hydroxides of vanadium:				
Canada	153	2,600	--	--
France	26,100	442,000	304	48,600
Germany	4,660	86,500	5	4,490
South Africa	4,710	77,200	--	--
United Kingdom	--	--	10,500	152,000
Total	35,600	608,000	10,800	205,000
Vanadium metal, including waste and scrap: (gross weight)				
Dominican Republic	50,700	33,500	--	--
Estonia	2,910	29,000	--	--
France	--	--	138	8,500
Germany	20,300	839,000	56,300	588,000
Korea, Republic of	438	4,360	35,300	16,700
Russia	21,100	296,000	4,410	182,000
South Africa	700,000	13,000,000	--	--
United Kingdom	200	3,140	5	15,900
Total	796,000	14,200,000	96,100	811,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ May include catalysts containing vanadium pentoxide.

Source: Bureau of the Census.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES AND SLAG 1/

(Kilograms, vanadium pentoxide content)

Material and country	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Ash and residues:				
Argentina	5,290	$2,910	--	--
Canada	610,000 r/	573,000 r/	1,650,000	$1,010,000
Dominican Republic	--	--	23,100	16,600
France	849	6,840	--	--
Germany	328,000	107,000	5,150	3,960
Italy	122,000	69,300	--	--
Korea, Republic of	7,890	1,580	--	--
Kuwait	--	--	3,640	22,700
Mexico	997,000	4,690,000	781,000	2,560,000
Netherlands	3,530	18,800	13,000	7,050
Netherlands Antilles	381,000	136,000	87,900	168,000
Portugal	--	--	7,130	6,470
Spain	13,000	8,890	--	--
United Kingdom	237,000	311,000	14,800	3,260
Venezuela	35,800 r/	17,600 r/	--	--
Total	2,750,000 r/	5,940,000 r/	2,590,000	3,810,000
Slag, from the manufacture of iron and steel: 2/				
South Africa	1,770,000 r/	5,850,000	1,470,000	5,670,000

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ As adjusted by the U.S. Geological Survey.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS 1/ 2/

(Kilograms, vanadium content)

Material and country	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Sulfates	--	--	25	$14,900
Vanadates:				
Germany	576	$28,200	3,360	76,500
Japan	131	7,890	--	--
South Africa	43,100	246,000	73,900	553,000
Switzerland	--	--	8	5,240
United Kingdom	300	94,800	--	--
Total	44,100	376,000	77,200	634,000
Hydrides and nitrides:				
Canada	2,910	65,000	--	--
Japan	1	2,500	--	--
South Africa	--	--	255,000	4,630,000
Total	2,910	67,500	255,000	4,630,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Comprises vanadium ore and miscellaneous vanadium chemicals.

Source: Bureau of the Census.

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TABLE 9
WORLD VANADIUM PENTOXIDE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1996 1/ 2/

(Metric tons of contained vanadium)

Country	Rated capacity 3/
Austria	1,500
Canada	770
Chile	2,300
China	8,200
Russia	9,500
South Africa	27,200
United States	11,000
Venezuela	2,500
Other	550
Total	63,500

1/ Data are rounded to three significant digits; may not add to total shown.
2/ Includes vanadium pentoxide in vanadiferous iron slags and petroleum refinery residues.
3/ Includes capacity of operating plants as well as plants on standby status.

TABLE 10
VANADIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained vanadium)

Country	1992	1993	1994	1995	1996 e/
Production from ores, concentrates, slag: 3/					
China (in vanadiferous slag product) e/	4,700	5,000	5,400 r/	7,000 r/	7,000
Hungary e/	200	200	200	200	200
Kazakstan e/	1,400	1,200	878 4/	924 4/	900
Russia e/	11,000	10,000	10,000	11,000	11,000
South Africa	14,285 r/	15,051	15,229 r/	16,297 r/	16,000
United States (recoverable vanadium)	W	W	W	W	W
Total	31,600 r/	31,500	31,700	35,400 r/	35,100
Production from petroleum residues, ash, and spent catalysts: 5/					
Japan e/	245	252	252	245	245
United States	1,350	2,870	2,740	1,990	3,730 4/
Total	1,590	3,120	2,990	2,240	3,980
Grand total	33,200 r/	34,600	34,700	37,700 r/	39,100

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ In addition to the countries listed, vanadium is also recovered from petroleum residues in Germany and several other European countries, but available information is insufficient to make reliable estimates. Table includes data through June 13, 1997.
3/ Production in this section is credited to the country that was the origin of the vanadiferous raw material.
4/ Reported figure.
5/ Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.

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VERMICULITE

By Michael J. Potter

Vermiculite is a micalike mineral that has the ion-exchange properties of zeolites and some clays. Beneficiation of vermiculite ore yields concentrate that is typically 90% vermiculite and 10% grit or rock. When a particle of vermiculite is heated rapidly to about 900 °C, the normally flat plate expands as much as twentyfold into an accordionlike, lightweight particle. This forms the basis for much of the commercial application of this mineral (Hindman, 1996).

Production

The total of U.S. vermiculite concentrate sold and used was withheld to avoid disclosing company proprietary data. The amount of exfoliated vermiculite sold and used was 135,000 metric tons compared with 130,000 tons in 1995. Domestic production data for vermiculite were derived by the U.S. Geological Survey (USGS) from two separate voluntary surveys—one for domestic mine-mill operations and the other for exfoliating plants. Of the four known mine-mill operations, data were obtained for two operations, representing a response rate of 50%. Production for the two nonrespondents was estimated by the USGS based on previous years' production levels and estimates. Of the 19 known active exfoliating plants, data were obtained from 16 for a response rate of 84%. Output for the three nonrespondents was estimated by the USGS by using previous years' production levels.

Domestic producers of vermiculite concentrate were W.R. Grace & Co. from its operation at Encore, SC, Virginia Vermiculite Ltd. with operations near Woodruff, SC, and in Louisa County, VA, and Patterson Vermiculite Co. near Enoree, SC.

U.S. output of exfoliated vermiculite from 15 known companies came from 19 plants in 11 States. *(See table 3).* Of these plants, four in four States were operated by W.R. Grace. The largest producing States of exfoliated vermiculite were estimated to be, in descending order of output sold and used, South Carolina, Ohio, Pennsylvania, Arizona, Illinois, Arkansas, New Jersey, and Florida.

Prices

Yearend prices for U.S. vermiculite concentrate, ex-plant, bulk, converted to dollars per metric ton ranged from $143 to $220. For South African material, crude, bulk, f.o.b. barge, Gulf Coast, converted to dollars per metric ton, prices ranged from $127 to $209 (Industrial Minerals, 1996).

World Review

Table 5 lists approximations of rated annual capacity for vermiculite concentrate plants as of December 31. Because actual capacity data were generally not available, capacities for most countries were considered to be equal to their highest production levels during the past 5 years.

In South Africa, the decrease in output of vermiculite concentrate was reportedly because of unusually high rainfall in the first quarter. Another factor was the delay in commissioning the new fluidized bed drying furnaces at Palabora Mining Co. Ltd., the world's largest producer (Palabora Mining Co. Ltd., 1996).

Dinidza Vermiculite Mining (Pvt.) Ltd. in Zimbabwe continued with an expansion program to increase concentrate production to 1,000 tons per month by July 1996 (Hindman, 1996).

Outlook

The largest enduse of vermiculite in recent years has been in potting soils and other horticultural and fertilizer products. Vermiculite also is used in building boards, such as plaster board, some lightweight wallboard, and various refractory board products. Potential new applications of vermiculite include detoxification of water and soil, nuclear waste containment and removal, and industrial spill containment and cleanup.

With the absence of large particle-sized vermiculite production in the United States and the use of imported concentrates to fill this void, there has been substantial interest in developing new vermiculite sources in the Western United States (Hindman, 1996).

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[1]Prior to January 1996, published by U.S. Bureau of Mines.

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TABLE 1
SALIENT VERMICULITE STATISTICS 1/

(Thousand metric tons and thousand dollars)

	1992	1993	1994	1995	1996
United States:					
Sold and used by producers:					
Concentrate 2/	190	190	177	171	W
Exfoliated	140	140	130	130	135
Value	$45,900	$46,700	$43,600	$39,400	$45,300
Average value 3/	$328	$338	$335	$306	$334
Exports to Canada e/	8	7	7	6	8
Imports for consumption e/	40	30	30	30	48
World: Production 4/	456	490	484	482 r/	266

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Values are withheld to avoid disclosing company proprietary data.
3/ Based on unrounded data.
4/ Excludes production by countries for which data were not available.

TABLE 2
EXFOLIATED VERMICULITE
SOLD AND USED IN THE UNITED STATES, BY END USE 1/

(Metric tons)

	1995	1996
Aggregates:		
Concrete 2/	11,700	16,900
Plaster	1,400	3,220
Premixes 3/	W	W
Total	W	W
Insulation:		
Loose-fill	W	W
Block	14,200	12,000
Other 3/	W	W
Total	33,600	27,100
Agricultural:		
Horticultural	26,800	26,500
Soil conditioning	14,500	19,700
Fertilizer carrier e/	30,400	29,300
Total e/	71,700	75,500
Other 4/	W	W
Grand total	130,000	135,000

e/ Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total" and/or "Grand total."
1/ Data rounded to three significant digits; may not add to totals shown.
2/ Includes acoustic, fireproofing, and texturizing uses.
3/ Includes high-temperature and packing insulation and sealants.
4/ Includes various industrial, etc., uses not specified.

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TABLE 3
ACTIVE VERMICULITE EXFOLIATION
PLANTS IN THE UNITED STATES IN 1996

Company	County	State
A-Tops Corp.	Beaver	Pennsylvania.
W. R. Grace & Co., Construction Products Div.	Jefferson	Alabama.
Do.	Maricopa	Arizona.
Do.	Broward	Florida.
Do.	Greenville	South Carolina.
Palmetto Vermiculite Co., Inc.	Spartanburg	Do.
Patterson Vermiculite Co.	Laurens	Do.
P.V.P. Industries	Trumbull	Ohio.
The Schundler Co.	Middlesex	New Jersey.
O.M. Scott & Sons.	Union	Ohio.
Southwest Vermiculite Co., Inc.	Bernalillo	New Mexico.
Strong-Lite Products Corp.	Jefferson	Arkansas.
Strong Products Corporation	La Salle	Illinois.
Thermic Refractories, Inc.	Macoupin	Do.
Thermo-O-Rock, Inc.	Maricopa	Arizona.
Do.	Washington	Pennsylvania.
Verlite Co.	Hillsborough	Florida.
Vermiculite Industrial Corp.	Allegheny	Pennsylvania.
Vermiculite Products, Inc.	Harris	Texas.

TABLE 4
VERMICULITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Argentina	--	38	32 r/	44 r/	50
Brazil	11,615	14,541	16,000	17,000 r/ e/	17,000
Egypt e/	500	500	500	500	500
India	1,609	1,485	1,903 r/	1,688 r/	1,750
Japan e/	15,000	15,000	15,000	15,000	15,000
Kenya	2,291	1,961	1,110 r/ e/	457 r/	500
Mexico	125	134	300	225 r/	225
Russia e/	60,000	50,000	40,000	40,000	30,000
South Africa	170,399	211,143	223,478	221,748	186,082 3/
United States (sold and used by producers) 4/	190,000	190,000	177,000	171,000	W
Zimbabwe	4,300	5,032	8,184	13,742 r/	15,000
Total	456,000	490,000	484,000	482,000 r/	266,000 5/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Excludes production by countries for which data are not available and for which general information is inadequate for formulation of reliable estimates. Table includes data available through July 22, 1997.

3/ Reported figure.

4/ Concentrate.

5/ Excludes U.S. data.

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TABLE 5
WORLD VERMICULITE ANNUAL
PRODUCTION CAPACITY
DECEMBER 31, 1996

(Thousand metric tons)

Country	Rated capacity 1/ 2/
North America:	
Mexico	(3/)
United States	190
Total	190
South America:	
Argentina	(3/)
Brazil	17
Total	17
Europe:	
Russia e/	60
Africa:	
Egypt e/	1
Kenya	2
South Africa	223
Total	226
Asia:	
India	2
Japan e/	15
Total	17
World total	510

e/ Estimated.
1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Excludes countries for which data were not available.
3/ Less than 1/2 unit.

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WOLLASTONITE

By Robert L. Virta

Wollastonite is a calcium metasilicate ($CaSiO_3$). It has a theoretical composition of 48.3% calcium oxide and 51.7% silicon dioxide but it may contain trace to minor amounts of aluminum, iron, magnesium, manganese, potassium, and sodium. Wollastonite occurs as massive or short prismatic crystals that cleave into massive to acicular fragments. It usually is white but also may be gray, brown, or red depending on its composition.

Wollastonite forms when either impure limestones are metamorphosed (subjected to heat and pressure) or silica-bearing fluids are introduced into calcareous sediments during metamorphic processes. In both cases, calcite reacts with silica to produce wollastonite and carbon dioxide.

Deposits of wollastonite have been found in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah. These deposits are typical skarns containing wollastonite as the major component and calcite, diopside, garnet, idocrase, and/or quartz as minor components.

Production

Wollastonite has been mined commercially in California and New York. The California deposits, which were in Inyo, Kern, and Riverside Counties, were mined between 1930 and 1970. These operations were limited in size, producing only a few thousand tons per year for ceramics, decorative stone, paint, and mineral wool production.

In New York, deposits in Essex and Lewis Counties have been mined since the 1950's. Two companies currently are mining wollastonite. NYCO Minerals Inc. operates a mine in Essex County, and R.T. Vanderbilt Co. Inc. operates a mine in Lewis County. The NYCO deposit contains wollastonite, garnet, and diopside. The ore is processed at the Willsboro plant where the diopside and garnet are removed by using high-intensity magnetic separators. NYCO also chemically modifies the surfaces of some of its wollastonite products. The Vanderbilt deposit in Lewis County contains wollastonite, calcite, and diopside. The ore is processed at the Balmat plant.

Domestic wollastonite sales increased slightly from that of 1995.

Consumption

The major uses of wollastonite are in ceramics, paint, and plastics and as a substitute for asbestos. It also is used in adhesives, friction products (brakes and clutches), joint compounds, refractories, wallboard, and metallurgical applications. In ceramics, wollastonite decreases shrinkage and gas evolution during firing, increases green and fired strength, permits fast firing, and reduces crazing, cracking, and glaze defects. As a filler in paint, wollastonite reinforces the paint film, acts as a pH buffer, improves its resistance to weathering, reduces pigment consumption, and acts as a flatting and suspending agent. In plastics, it improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures, and, when surface treated, improves the adhesion with polymers. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, inert, stable at high temperatures, and a good reinforcer. In Europe, another major use is as a flux for welding and controlling casting speed during continuous casting of steel.

Prices

Prices per metric ton, for wollastonite, exworks, acicular, were $180 for -200 mesh; $224 for -325 mesh; and $248 for -400 mesh. The prices per ton, exworks, were $308 for acicular, high-aspect-ratio material and $620 for ground (10 micron) material. Prices per ton for wollastonite, f.o.b. plant, bulk, were $170 for 200 mesh and $214 for 325 mesh (Industrial Minerals, 1996b). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade

About 1,380 tons of wollastonite was imported and 4,080 tons was exported in 1996, according to the Journal of Commerce (JoC) Port Import/Export Reporting Service. Most of the wollastonite was imported from India, only small tonnages were imported from China and Japan. A large percentage of the wollastonite exports went to Japan. Other major markets were the South Pacific region, South America, and Central America. The JoC data do not include wollastonite imported from or exported to Canada and Mexico.

World Review

Worldwide production of wollastonite is estimated to be between 500,000 and 550,000 tons in 1996. Wollastonite production was 22,300 tons in Finland; 90,000 tons (estimated) in India; and 29,000 tons (estimated) in Mexico. Wollastonite production in China is more difficult to ascertain. Although industry experts place production between 100,000 tons and

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250,000 tons, it is more likely to be nearer 250,000 tons. Chile, the Czech Republic, Namibia, North Korea, Pakistan, South Africa, and Turkey also produce small amounts of wollastonite. Industry experts place U.S. production at 150,000 tons.

Brazil.—The Instituto de Pesquisas Tecnologicas do Estado de Sao Paulo (IPT) began accepting bids for mineral rights to a wollastonite deposit located near Itaoca. The deposit consists of two ore bodies. One ore body contains 800,000 tons of fine-grained skarn that comprises 48% wollastonite, 23% garnet, 8% diopside, and 21% plagioclase and other minerals. The other contains 50,000 tons of ore that comprises more than 60% wollastonite, 13% garnet, and 9% diopside, as well as various amounts of calcite, feldspar, and vesuvianite (Industrial Minerals, 1996c).

Canada.—Super Twins Resources Ltd. completed a mine feasibility study at its Isk Wollastonite project site in British Columbia. The company contracted for mine and mill site design (North American Minerals News, 1996c). Orleans Resources Inc. received financing for development of its St. Ludger de Milot, Quebec, deposit and began construction of the processing facility (North American Minerals News, 1996a).

Cuba.—In Cuba, Geominera SA was looking into a joint wollastonite venture at Ariamo, Cienfuegos (North American Minerals News, 1996b).

Kazakstan.—The private Kazakstan mining company, Olva, mines wollastonite in the Zhezkazgan region where reserves are estimated to be 14.5 million tons. Mine capacity is reported to be 150,000 tons per year. Olva is looking to expand its markets. In the past, wollastonite sales were limited to small defense markets (Industrial Minerals in the CIS, 1996).

Mexico.—NYCO Minerals Inc. continued construction of its mill near Hermosillo. The plant will have a capacity of 200,000 tons per year. The mine supplying the mill has reserves of 82 million tons of high-aspect-ratio wollastonite; the average grade is 60%. Flotation will be used to separate calcite. The wollastonite will be sold to plastics, ceramics, asbestos replacements, metallurgy, and various other markets. Primary markets will be in Europe, Asia, and South America. (Industrial Minerals, 1996a).

Outlook

The outlook for wollastonite looks good as existing markets expand and new markets are developed. With the opening of NYCO's plant in Mexico in late 1997, aggressive marketing of industrial minerals by the Chinese, and the anticipated development of Canadian deposits in the next year or two, wollastonite markets will be much more competitive than in the past.

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ZEOLITES

By Robert L. Virta

Zeolites are hydrated aluminosilicates of the alkaline and alkaline-earth metals. About 40 natural zeolites have been identified during the past 200 years, the most common of which are analcime, chabazite, clinoptilolite, erionite, ferrierite, heulandite, laumontite, mordenite, and phillipsite. More than 150 zeolites have been synthesized. Some of the more common synthetic zeolites are zeolites A, X, and Y and ZMS-5. Natural and synthetic zeolites are used commercially because of their unique adsorption, ion-exchange, molecular sieve, and catalytic properties.

Natural Zeolites

Commercial zeolite deposits in the United States are associated with the alteration of volcanic tuffs in saline, alkaline lake deposits, and open hydrologic systems. The deposits are in Arizona, California, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Wyoming. The major components of these deposits are chabazite, clinoptilolite, mordenite, and phillipsite. Erionite, orthoclase and plagioclase feldspars, montmorillonite, opal, quartz, and volcanic glass are present in some deposits.

Production.—Conventional mining techniques are used to mine natural zeolites. The overburden is removed to allow access to the ore, which is stripped for processing by using front-end loaders or tractors equipped with ripper blades. The ore is dried and then crushed by using either jaw crushers or roller mills. The milled ore is packaged directly for shipping or is screened to remove fine material when a granular product is required. In some cases, a pelletized product also is produced.

Six companies mined natural zeolites in the United States in 1996. *(See table 1.)* Although Steelhead Specialty Minerals did not mine in 1996, the company reported sales of natural zeolites. Clinoptilolite was mined and/or processed in Nevada, New Mexico, Oregon, and Texas; chabazite was mined in Arizona. Total domestic production was 39,300 metric tons.

Consumption.—About 28,500 tons of natural zeolites was sold in 1996, a 16% decrease from that of 1995. The various end uses for natural zeolites included in decreasing order of consumption, pet litter, animal feed, fertilizer carrier, odor control, oil absorbent, aquaculture, waste-water cleanup, catalysts, desiccant, gas absorbents, water purification, and paper applications. Pet litter and animal feed applications accounted for over 70% of the sales. Consumption increased for animal feed, aquaculture, catalyst, fertilizer carrier, gas absorbent, oil absorbent, paper, water purification, and waste-water cleanup applications. Sales for animal feed and fertilizer applications increased significantly, but in all other cases, the increases in sales were less than 200 tons. Consumption declined for desiccant, odor control, and pet litter applications. The largest decrease was for pet litter applications.

The American Resources Corp. Inc. (ARC) continued its research into additional markets for clinoptilolite from its Ash Meadows, NV, deposit. In 1993, ARC had purchased the Ash Meadows deposit from East West Minerals Inc., as well as a mordenite deposit in Rome, OR, and a clinoptilolite-chabazite deposit in Bowie, AZ. The company currently markets zeolites for horticultural applications and odor control in nonagricultural and agricultural fields. ARC is looking to land-reclamation projects, hydroponics, aquaculture, and gas separation as some of the more lucrative future markets for their zeolites (North American Minerals News, 1996).

Prices.—Prices for natural zeolites vary with zeolite content and processing.

For industrial or agricultural applications, prices ranged from $30 to $70 per ton for granular products down to 40 mesh and from $50 to $120 per ton for -40 mesh to -325 mesh ground material. For consumer products, such as for pet litter, fish-tank media or deodorant applications, prices ranged from $0.50 to $4.50 per kilogram (Holmes, 1994). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade.—Less than 100 tons of natural zeolite was imported and from 400 to 500 tons was exported in 1996, according to the Journal of Commerce (JoC) Port Import/Export Reporting Service. Most of the zeolites imported into the United States in 1996 were either synthetic or mineral specimens, not bulk natural zeolites. The JoC data does not include zeolites imported from or exported to Canada and Mexico (Journal of Commerce, 1996).

World Review.—Worldwide production of natural zeolites was estimated to be more than 3 million tons. Estimates, in tons, for individual countries were Bulgaria, 45,000; Canada, 4,000; China, 2.5 million; Cuba, 500,000 to 600,000; Hungary, 10,000 to 20,000; Italy, 4,000; Japan, 140,000 to 160,000; Slovakia, 12,000; South Africa 1,000 to 2,000; the United States, 39,300; and the former U.S.S.R., 10,000. Small amounts of natural zeolites also were produced in Argentina, Australia, Germany, and Indonesia. Zeolites were used in Bulgaria in agricultural applications, such as animal feed additives, odor control, and soil amendments. Much of the zeolite production was used in pozzolanic cements and various other industrial and agricultural applications in China, and agricultural applications such as animal feeds and soil additives, and unspecified export markets in Cuba. In Japan, zeolites were used for water treatment, desiccants, agricultural applications (that is, animal feed and insecticide carrier) and as a paper filler.

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Silver and Baryte Ores Mining Co. SA announced that it would begin mining and processing natural zeolites in northern Greece. The plant will produce five grades of clinoptilolite and have a capacity of 50,000 tons per year (Industrial Minerals, 1996).

Current Research and Technology—The U.S. Geological Survey tested the affinity of clinoptilolite-rich rocks (CRR) from six deposits in the western United States for nitrogen compounds in fertilizers. The objective was to determine the effectiveness of using CRR as fertilizer carriers; that is, would they would enhance the cation-exchange capacity of soils to which they were applied and would they slowly release fertilizers applied to the soil. Six low-sodium CRR's were exposed to potassium chloride, sodium chloride, and ammonium chloride solutions, rinsed, dried, and analyzed for potassium, calcium, and nitrogen content. The pH's of the solutions also were tested after the exchange procedure. Exchange capacities for ammonium (NH_4^+) varied considerably. Amounts of nitrogen (in the form of NH_4^+ and in soluble forms of ammonium and nitrate salts) after exposures to 57.1 weight percent ammonium nitrate solutions ranged from 94 to 164 pounds of nitrogen per ton of CRR. During the exchange process, calcium and potassium were lost from the clinoptilolite structure. The study concluded that CRR showed potential for increasing the cation-exchange capability of the soil by temporarily extracting NH_4^+ when highly soluble NH_4^+ rich fertilizers are applied to crop fields (Desborough, 1996).

Zeolite fines were pelletized by using a lignosulfonate as the binder. The lignosulfonate was burned off in an oxygen-reducing environment, leaving a carbon residue. The resulting pellets were durable, permeable, and insoluble in water. The agglomerated pellets had more ion-exchange capacity than untreated zeolites and were capable of removing high concentrations of lead (Peterson, 1996).

A 2-year trial of a zeolite-based heat-storage system began in the Munich, Germany, school system. The trial uses 7 tons of zeolite that is dried by a 130 °C steam-based heating system during off-peak hours. Moist air is drawn over the dried zeolite during the day, and the heat released by the zeolites (heat of adsorption) is used to warm the water in the building's conventional warm-water heating system. The energy stored in the zeolite beds ranges from 130 to 200 kilowatt-hours per cubic meter, which is two to three times that of warm-water storage systems (Chemical Engineering, 1996b).

Synthetic Zeolites

Absorbents.—Crosfield Chemicals developed an absorbent that selectively absorbs water in the presence of small molecules. Its uptake of moisture is slower than other materials already in use, making its manufacture and storage easier. Potential uses are in zinc and aluminum anticorrosion paints (European Chemical News, 1996a). Corning Inc. developed a catalyst that uses a zeolite adsorber to reduce cold-start emissions. Cold exhaust is diverted through the zeolite adsorber until the catalytic converter reaches operating temperature. Hydrocarbon emissions are reduced to 0.03 gram per mile, well below the U.S. standard set for 2000 (Chemical and Engineering News, 1996b).

Catalysts.—UOP Corp. installed a 66,000-ton-per-year cumene production unit for JLM Chemicals Inc. in Illinois. The unit produces a 99.95% pure cumene product and uses a zeolite catalyst instead of a solid phosphoric acid catalyst because the zeolite catalysts increases plant capacity (European Chemical News, 1996b).

Enichem S.p.A. also commissioned a zeolite-based cumene production plant near Porto Torres, Sardinia. Capacity will be increased by 30% to 40% with a reduction in operating costs by 20% to 30% (Chemical Engineering, 1996a).

Detergents.—PQ Corp. introduced a new zeolite for high-pressure-spray car-washing applications. The zeolite acts as a water softener and a cleaner and polisher (Chemical Market Reporter, 1996).

Current Research and Technology.—A high-silica zeolite with pore openings formed by 14, rather than 12 atoms, has been developed at the California Institute of Technology and the University of Texas. The new form reportedly is stable at 1,000 °C. The larger pore openings will enable the zeolite to catalyze a wide range of hydrocarbon reactions (Chemical Week, 1996). Silica-free zeolite β and aluminum-free, titanium-containing zeolite β have been synthesized without a need for zeolite seed crystals. The zeolites nucleated spontaneously and grew in a hydrothermal system containing tetraethylammonium and fluoride ions. Silica-free zeolite β has potential applications in acid-catalyzed reactions. Both varieties are hydrophobic and have improved thermal stability over conventionally crystallized forms (Chemical and Engineering News, 1996b). A new method of producing synthetic zeolite structures was developed at the Royal Institution and the University of Liverpool. With this technique, templates that are typically organic are added to the solution before hydrothermal synthesis begins. The catalyst framework condenses around the templates, which are later removed, and a structure with predetermined pores and channels remains. The method will allow researchers to synthesize zeolites with specific microporous structures (European Chemical News, 1996c).

Outlook

The outlook for natural zeolites remains good. Producers are expanding their market lines and are working more closely with customers to cater to the customer's specific needs. Sales should continue to be in the 30,000- to 40,000-ton-per-year range.

With regard to synthetic zeolites, growth rates are expected to slow down compared with the past several years. Detergent markets in North America should show slow growth with the bulk of substitution of zeolites for phosphates completed. Although fluid cracking catalyst (FCC) markets declined in 1995 and 1996 owing to lower demand, FCC manufacturers believe that Asian markets will increase in the near future.

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TABLE 1
DOMESTIC ZEOLITES PRODUCERS, 1996

State and company	Type of zeolite
Arizona:	
GSA Resources Inc.	Chabazite.
UOP Inc.	Do.
Nevada:	
American Resource Corp.	Clinoptilolite.
New Mexico:	
St. Cloud Mining Co.	Do.
Oregon:	
Teague Mineral Products Co.	Do.
Texas:	
Zeotech Corp.	Do.

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ZINC

By Jozef Plachy

In 1996, domestic zinc mine production declined by more than 2%. Zinc was extracted from 23 mines in 8 States. *(See tables 2 and 3.)* During the year, four mines ceased production, and one mine was reactivated. For the sixth consecutive year, Alaska was the leading zinc mining State, and was followed by Tennessee, New York, Missouri, and Montana. U.S. mine production greatly exceeded smelter capacity, resulting in more than two-thirds of the zinc concentrate being exported, mainly to Canada. Based on the recoverable content and the average annual U.S. price, the value of zinc mine production exceeded $600 million.

The 1996 zinc metal production by the three primary smelters-refineries from domestic and a small amount of imported concentrate was about 3% lower than that of 1995. *(See table 4.)* The imbalance between concentrate production and smelter capacity may be partially redressed by planned capacity increases at the Clarksville, TN, and the Sauget, IL, smelters.

Apparent consumption decreased slightly, and imports of zinc metal decreased by more than 3%. About one-half of the refined zinc was used for galvanizing.

U.S. producer prices, which are based on the London Metal Exchange (LME) daily cash price and include a premium, increased by more than 4% between January and December. However, the average price for zinc was slightly less than that of the previous year, in spite of an almost 25% decline in LME stocks.

Despite numerous mine closings, world mine production increased by about 3%, to 7.4 million metric tons. Canada remained the world's largest producer, and was followed by Australia, China, Peru, and the United States. These countries accounted for about 63% of total world production of zinc concentrates. *(See table 17.)* Total zinc metal production decreased slightly, to 7.5 million tons. China, Canada, Japan, and the United States accounted for about 38% of total world zinc metal production. *(See table 18.)* LME stocks declined from 664,700 tons at the beginning of January to 506,800 tons by yearend. Total world stocks were down by 20%, to 922,000 tons at yearend, equivalent to 6.5 weeks of consumption.

Legislation and Government Programs

The Defense Logistics Agency (DLA) is authorized (Public Law 102-484) to sell 45,000 tons (50,000 short tons) of zinc per fiscal year from the National Defense Stockpile (NDS) as long the sale does not cause undue disruption of the zinc market. Actual sales amounted to 16,512 tons (18,201 short tons). The DLA has maintained that the market for its stockpiled zinc metal, 90% of which is either high grade or prime western grade, included the whole zinc market; the American Zinc Association (AZA), however, insisted that the market for stockpiled zinc is principally the high-grade zinc market. To settle the disagreement, the U.S. Congress asked the General Accounting Office (GAO) to investigate the dispute between the AZA and the DLA. The GAO concluded that the usual market for stockpiled zinc is the total U.S. zinc market, which amounts to more than 1.2 million tons, dwarfing the amount sold from the stockpile (U. S. General Accounting Office, 1996).

In August, the U.S. Department of the Interior invited the public to participate in the revision of regulations for lead and zinc mining on Indian Reservations by submitting written comments to the Bureau of Indian Affairs. The proposed revision pertained to leasing of the Quapa Indians' land, which is under the jurisdiction of Ottawa County, OK, for the discovery, testing, development, mining, and processing of all lead and zinc minerals. The proposed revisions, if implemented, will set a precedent for mining on other Indian Reservations (Bureau of Indian Affairs, 1996).

On September 16, 1996, the U. S. Environmental Protection Agency (EPA) granted an exemption from hazardous waste control to Bekaert Steel Corp. of Rogers, AR. The decision involved the treatment of wastewater sludge from electroplating operations at the Rogers facility. The EPA determined that the concentration of zinc was below the level of regulatory concern and should not present a hazard to human health or the environment. The regulation requires that the content of wastewater be analyzed annually. The request was backed by the AZA, which used this opportunity to request that zinc be removed permanently from the list of hazardous wastes, disposal of which is regulated by the Land Disposal Restrictions, to "additional constituents" which can be disposed of in municipal dumps.

Production

Mine Production.—U.S. zinc mine output, expressed in recoverable zinc content, declined by more than 2% in 1996, mainly because of several mine closings—the Rosiclare Mine, IL, in January, the New Market Mine, TN, in September, and the Jefferson City Mine, TN, in October—and the temporary closure of the Leadville Mine, CO, in December. The potential concentrate shortfall was partially offset by the reopening of the Greens Creek Mine, AK, in July.

The production of zinc ore at the Red Dog Mine in Alaska, owned by NANA Regional Corp. and leased by Cominco Ltd.'s subsidiary, Cominco Alaska Inc., declined by about 7%, to 2.1

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million tons. Because of improved milling efficiency—from 75% in 1995 to 83% in 1996—concentrate production increased by 2,000 tons, to 587,200 tons, which contained 324,722 tons of zinc (Cominco Ltd., 1997).

Cominco began a $104 million expansion of the Red Dog Mine that was expected to increase production by about 40% during the next 3 years, with most of the increase expected in 1999. Most of the planned increase was to come from raising the rate of production in the main ore body, estimated to have a remaining life of as much as 20 years. Together with the recently discovered Aqqaluk zone, which doubled the size of zinc reserves at Red Dog while maintaining a combined zinc grade of 16%, the total reserves at Red Dog were expected to be sufficient for at least 40 years of operation (Mining Journal, 1996g).

Encouraged by the recent discovery, Cominco continued to explore for further deposits around the Red Dog Mine. The latest discovery included zinc-lead-silver mineralization immediately north of the Aqqaluk zone. Two holes, drilled 140 meters apart, intersected a mineralized zone grading from 12% to 26% zinc with small amounts of lead and silver. The new zone was only partially delineated, and additional drilling was planned for 1997 (Mining Record, 1996a).

Zinc is Cominco's largest single source of revenue, representing 48% of the total. To maintain its prominence, 46% of the company's $48 million worldwide exploration budget was directed towards zinc prospects, mainly in North America (Northern Miner, 1997a).

Korea Zinc Co. Ltd., of the Republic of Korea, secured a 25% stake in the joint venture Tintic Utah Metals LLC. The joint venture was headed by Chief Consolidated Mining Co., the United States, which had a 50% interest; Akiko Gold Resources, Canada, held the remaining 25%. The venture planned to develop the New Burgin polymetallic deposit in Utah and to explore the surrounding 3,600-hectare (9,000-acre) Tintic property for additional mineralization. Thyssen Mining Construction of Canada, Ltd., the North American Subsidiary of Thyssen Schachtbau GmbH of Germany, agreed to conduct preliminary engineering design and cost evaluations for shaft sinking, underground development, and contract mining. According to Sunshine Mining, the previous owner, the deposit has minable reserves of 1.4 million tons of ore containing 6.7% zinc, 21% lead, and 566 grams of silver per ton. The project is expected to come on-stream in late 1998 (Mining Journal, 1996d).

Because of depressed concentrate prices and high treatment charges, ASARCO Incorporated decided to close its Leadville Mine in Colorado at yearend. As the first employees of the already depleted work force were leaving the mine in mid-December, Asarco reconsidered its decision and decided to resume mining operations in 1997. The restart of operations was to be phased in during January with full employment in February; full production was expected by mid-March (Platt's Metals Week, 1996).

The Greens Creek Mine, the polymetallic underground zinc-lead-silver-gold mine on Admiralty Island off Juneau, Alaska, reopened at the end of July, 5 months ahead of schedule. The mine is owned by a joint venture of Kennecott Greens Creek Mining Co. (70.3%) and Hecla Mining Co. (29.7%). Between 1993 and 1995, when the mine was closed, exploration efforts around Greens Creek successfully identified a high-grade ore deposit called the Southwest Zone. The new deposit allowed profitable mining at prevailing metal prices during the last 5 months of 1996. The metal content of the ore produced in 1996 amounted to 10,843 tons of zinc, 3,810 tons of lead, 193 tons of copper, 77 tons of silver, and 233 kilograms of gold. The full annual production rate of about 40,000 tons of zinc was expected in the first quarter of 1997, when grinding and flotation circuits were to be completed. The total known reserves were expected to give Greens Creek a 17-year mine life at intended production rates. The owners of Greens Creek signed a land exchange agreement with the U.S. Forest Service for exploration rights to about 3,000 hectares (7,500 acres) of land surrounding the mine (Mining Record, 1996c).

Crandon Mining Co. was awaiting approval from Wisconsin State Government for its Rhinelander Mine. The deposit reportedly contains about 55 million tons of recoverable ore at grades of 9.4% zinc and 0.4% copper, with small amounts of lead and precious metals. The company anticipated building a 2-million-ton-capacity mill, producing between 200,000 and 300,000 tons of zinc concentrates and about 20,000 tons of combined copper-lead concentrate per year. At the planned production rate, the mine would be operational for about 28 years (Metal Bulletin, 1996d).

Smelter and Refinery Production.—Savage Zinc Inc., a subsidiary of Australia's Savage Resources Limited, applied to the Tennessee State Government for approval to increase the capacity of its Clarksville smelter from 100,000 to 260,000 tons of zinc per year. The approval process was expected to take more than a year, after which a detailed feasibility study would have to be completed. Savage Zinc also started processing refinery residues to improve the recovery of zinc and byproducts, including germanium. The company lost about 4,000 tons of metal output because of roaster difficulties in August. Part of the loss was made up from its own stocks, and the rest was purchased from outside sources, including metal purchased from the DLA (Metal Bulletin, 1996m).

In April, Korea Zinc Co. Ltd. acquired the Illinois-based 82,000-ton-per-year Sauget smelter from Big River Zinc Corp., a wholly owned subsidiary of Big River Resources. The Sauget smelter obtained most of its concentrate from mines in Tennessee and Missouri and imported about 20% of its feed from Canada, Mexico, and Peru. Six months after the purchase, Korea Zinc announced a two-part strategy to increase the output of its newly acquired smelter—the first focused on environmental issues, namely reducing waste, increasing recovery, and ensuring better environmental control and the second part called for expanding production from the current 88,000 to 120,000 tons per year, mainly by eliminating bottleneck problems (Fineberg, 1996a).

Secondary Production.—Between 1984 and 1996, world secondary zinc recovery increased three times faster than

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primary zinc metal production. Secondary recovery provided more than one-quarter of the world's refined zinc output in 1996. In the United States, secondary zinc recovery increased by about 7%, to 377,000 tons, equivalent to 31% of consumption. *(See tables 9 and 10.)* This rapid increase was caused by the introduction of new economically feasible technologies spurred by strict environmental protection laws.

One of the new dezincing technologies was developed by Metal Recovery Technologies Inc., in cooperation with the American Iron & Steel Institute and the U.S. Department of Energy. Metal Recovery began commercial dezincing operations at its new plant in East Chicago, IN, in October. The process involved washing galvanized steel scrap in two consecutive rolling drums containing a solution of sodium hydroxide to dissolve zinc, which is then removed from the solution by electrowinning. This new technology enabled a 99% rate of recovery in the form of 99.8% pure zinc powder. About 73,000 tons of high-grade black scrap (steel) per year and 1,750 tons of zinc per year is expected to be produced from the 75,000 tons of treated scrap. Owing to initial startup problems, only 50 tons of zinc powder was produced in 1996 (Metal Bulletin, 1996i).

Interamerican Zinc Inc. (IZI) moved its dross-processing operation from Adrian, MI, to a location adjacent to an aluminum recycling plant it is building with Alchem Aluminum Inc. in Coldwater, Michigan. The capacity of the new secondary zinc plant is the same as that of the Adrian plant—20,000 tons of continuous galvanizer grade zinc slab, making IZI the largest U.S. recycler of drosses from the steel galvanizing industry.

Consumption

Domestic data for zinc consumption was developed by the U.S. Geological Survey from voluntary surveys of U.S. operations. Large consumers were canvassed monthly, and smaller ones, annually. Between 65% and 70% of zinc-consuming companies were surveyed, of which about 70% responded. Consumption for nonrespondents was estimated on the basis of prior consumption and industry trends. Reported consumption of refined zinc accounted for about 65% of apparent metal consumption.

Apparent domestic consumption of slab zinc fell by 22,000 to 1,210,000 tons. Electrogalvanizing and hot-dip galvanizing, mainly for sheet and strip, continued to be the principal uses of zinc metal, consuming about one-half of total production. As the annual cost of metallic corrosion in the United States is estimated to be about $300 billion, it is not surprising that galvanizing is the largest application of zinc and is expected to continue to expand. Consequently, three new plants began operations in 1996—a 400,000-ton-capacity hot-dip plant in Delta, OH, a 350,000-ton-capacity hot-dip plant in Granite City, IL, and a 260,000-ton-capacity hot-dip/galvalume plant in Birmingham, AL. An additional three plants are to be added in 1997 and five more plants in 1998, raising galvanizing capacity by more than 4 million tons and consumption of zinc by about 120,000 tons. The largest consumers of hot-dipped galvanized steel are the construction and automotive sectors, using 45% and 33%, respectively (Christiansen, 1996).

Stocks

In 1996, the imbalance between supply and demand was offset by drawing down of stocks. In the United States, stocks of refined zinc decreased by nearly 5%. An even larger decrease was recorded by LME stocks, which fell by nearly 24%, to 506,800 tons, the lowest level since 1993. According to industry experts, the zinc market should remain in a substantial deficit during 1997 and possibly through 1998. While world metal production is forecast to rise to only 7.60 million tons, consumption is expected to reach 7.72 million tons, generating a deficit of 120,000 tons in 1997 (Mining Journal, 1997e).

Prices

The decline in stocks did not stimulate any noticeable price increase in 1996. Although the average domestic price for North American Special High Grade zinc was lower than that of the previous year, the daily price at yearend was nearly 4% higher than in the beginning of the year, indicating a possible upward turn in domestic prices in 1997. The price of zinc on the U.S. market consists of an LME base price plus a premium reflecting delivery fees, the availability of zinc, and other market conditions. The annual average premium was 4.61 cents per pound of refined zinc metal.

Foreign Trade

The pattern of U.S. trade in zinc has remained essentially unchanged for several years; refined (slab) zinc is the overwhelmingly important imported form, ore concentrates the overwhelmingly important exported form. Overall, net imports of zinc contained in all forms (ore through finished metallurgical products and compounds) changed little in 1996. The relatively high domestic zinc prices in the first half of 1995 had encouraged importation of slab zinc in that year. As the price eased in the latter months of 1995 and through the first 7 months of 1996, imports decreased somewhat. Nonetheless, imports of slab zinc were equivalent to about 68% of apparent consumption of slab zinc in 1996, compared with 70% in 1995—both figures were typical of the percentages in recent years. The majority of the imported slab zinc originated in ores from Cominco's Red Dog Mine, in Alaska, which were smelted and refined at Cominco's plant at Trail, BC, and shipped from Canada.

Because of growing domestic demand, coupled with ebbing demand in the Far East, exports of secondary zinc declined to about 45,500 tons, valued at $30 million. Imports of secondary zinc declined by 25%, to 32,000 tons, composing about 2.2% of annual consumption of zinc. Dross generated by continuous hot-dip galvanizers remained in high demand for domestic use and exports alike, with the price for the dross reaching up to

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80% of the cash LME price for zinc. Consequently, increased amounts of the dross were used by domestic secondary producers, reducing exports. With a nearly 70% share, Taiwan remained the largest importer of U.S. scrap, and was followed by India and Canada.

World Review

Australia.—Australian production of zinc concentrate increased by more than 14%, owing to the opening of the Hercules Mine, the reopening of the Potosi Mine, and the expansion of the Woodcutters Mine. Inauguration of the Century Mine in Queensland, however, was delayed until 1997. Rio Tinto Zinc Corp.-Conzinc Riotinto of Australia (RTZ-CRA) reportedly has been frustrated in its attempt to develop the Century deposit by the impasse in its negotiations with the local Waanyi people, who claim ownership of the land under Australia's Native Title Act. The deposit was discovered in 1990 by CRA, and reportedly has proven reserves of 116 million tons grading 10.2% zinc, 2.3% lead, and 38 grams of silver per ton of ore (Mining Journal, 1996i). Production was planned at 780,000 tons of zinc concentrate per year and 84,000 tons of lead concentrate per year. One-half of the proposed zinc concentrate was to be shipped to Pasminco's Budel smelter in the Netherlands, which requires zinc concentrates low in iron.

Pasminco's production of zinc concentrate in fiscal year 1995 (ending on June 30, 1996) was slightly lower than that of fiscal year 1994. All its production came from four mines—Broken Hill, Elura, Potosi, and Roseberry. Because of declining zinc content of the ore at the Broken Hill Mine, the 2.4-million-ton production had to be supplemented, at a rate of 200,000 tons per year, with ore from the nearby Potosi open pit mine. Pasminco also decided to resume production at its Hercules Mine in Tasmania, following the signing of a 2-year joint venture agreement with Mancala, a mining management and contracting company in Australia. Ore will be trucked to the nearby Roseberry mill, where it will augment zinc concentrate from the Roseberry underground mine by about 5,000 tons in the first year and close to 8,000 tons in the second year (Metal Bulletin, 1996l). Pasminco also proposed a joint venture to Coolgardie Gold, for exploration and possible development of its deposit in the Lawn Hill Platform, 50 kilometers southeast of the Century deposit and 150 kilometers north of the Mount Isa Mine. If commercially viable, then it could augment and eventually replace diminishing production at the Broken Hill Mine. Preliminary drilling results at Lawn Hill in October revealed a significant 11-meter-wide deposit grading 8.2% zinc and 1.6% lead at a depth of 103 meters (Metal Bulletin, 1996k).

Korea Zinc Co. Ltd. plans to build a new zinc refinery in Townsville, north Queensland. The first stage of the $775 million construction is to start in April 1997. Production is expected to begin in February 2000 at an initial level of 170,000 tons of zinc concentrate per year. According to the agreement between Korea Zinc and the Queensland Government, after completion of the first stage, Korea Zinc is to undertake a feasibility study for the second stage, which will include a lead smelter and an expansion of the zinc refinery (Mining Journal, 1996c).

Bolivia.—Most of the 1996 increase in Bolivia's zinc ore production came from the opening of the Don Francisco Mine and the expansion of the Andacaba Mine, both of which are located in southern Bolivia. The Don Francisco Mine began production in June and is scheduled to produce 200 tons per day in 1997. Ore reserves reportedly amount to 230,000 tons grading 18% zinc and 79 grams of silver per ton of ore. By 1998, the Don Francisco and the Andacaba Mines, which began expansion in summer 1996, were expected to yield 17,400 tons of zinc, 2,700 tons of lead, and 37 tons of silver per year. Andacaba's reserves were estimated to be 1.7 million tons grading 9.5% zinc, 3.3% lead, and 302 grams of silver per ton of ore. Both mines were purchased by the Denver-based Atlas Corp. in October for $4 million in cash and 4 million Atlas shares (Mining Journal, 1996f).

Canada.—The world zinc market was marked by the unexpected closures of several zinc mines at yearend. Because of low prices, a strong Canadian dollar, and technical problems, at least three Canadian mines closed. The first mine to cease operation was Goldstream Mine, owned by Bethlehem Resources Corp. The Faro Mine, owned by the Anvil Range Mining Corp., and the Gonzague-Langlois (formerly Grevet) Mine, owned by Cambior Inc., closed temporarily. If both of these remain closed in 1997, the already tight world concentrate supply will decline by about 230,000 tons. Despite these setbacks, the 1996 Canadian production of zinc in concentrate was about 10% higher than that of 1995 because of increased production at other mines and the reopening of the Gonzague-Langlois Mine during part of the year.

On December 20, Anvil Range Mining Corp. suspended mining operations at its Faro lead-zinc mine, Yukon Territory; 300 of the mine's 450 employees were affected. The Faro Mine comprises the Dy, the Grum, and the Vangorda deposits. The suspension reportedly resulted from a combination of production problems and weak metal prices. Delays in maintenance and scheduled repairs of the mill, as well as a lack of sufficient mining equipment, were said to have caused an 11% drop in output. In addition, the declining ore grade, from 8% combined zinc-lead in September to 6.7% in November, made the whole operation unprofitable. Milling operations were to continue for the first 3 months of 1997, processing the stockpiled low-grade ore at 50% of normal milling capacity. During that time, the whole operation was to be reevaluated and a decision made on whether to reopen the mine. Prior to its startup in 1995, the Grum open pit reportedly had 24.8 million tons of proven and probable reserves, grading 4.54% zinc, 2.74% lead, 46 grams of silver, and 0.7 grams of gold per ton of ore. Reserves of the Vangorda pit reportedly are nearly depleted but the nearby Dy deposit was said to contain an estimated 9.4 million tons of underground reserves grading 6.62% zinc, 5.5% lead, 80.3 grams of silver, and 0.82 gram of gold per ton. Because only about 20% of the surrounding area has been explored, a $4.4 million exploration program was launched in June. Prior to

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closure, planned production for 1997 was 170,000 tons of zinc in concentrate (Robertson, 1996).

After less than a year of operation, Montreal-based Cambior Inc. suspended production at its Gonzague-Langlois underground mine near Lebel-sur-Quévillon, northwestern Quebec. The December closure was caused by low metal prices and the need to modify the method used to mine certain parts of the deposit. The company expected to restart operations in the second quarter of 1997, provided market conditions are favorable. At the projected rate of production, mine life is expected to be at least 12 years. Proven and probable reserves are said to amount to 11 million tons grading 8.5% zinc, and containing small amounts of copper, gold, and silver. Concentrate production in 1996 was expected to amount to 62,000 tons of zinc, 3,000 tons of copper, 8.8 tons of silver, and 20 kilograms of gold in concentrates from 910,000 tons of ore (Mining Record, 1996b). Most of the zinc concentrate from the Gonzague-Langlois Mine was processed at Noranda's electrolytic zinc refinery in Valleyfield, Quebec, with a zinc recovery of 91%. The refinery reportedly is to receive $61 million from Noranda in 1997, one-half of which will be used to improve the hydrometallurgical process, and the remainder to treat and dispose of production waste.

China.—China's large-scale, Government-owned lead and zinc enterprises continued a series of mergers to reduce production costs and to improve profits. In 1995, the Huludao zinc plant and the Shenyang smelter formed Huludao Northeastern Nonferrous Metals Enterprise, while Lingnam Lead and Zinc Group, based in Shaoguan, was formed by the Shaoguan smelter and the Fankou lead and zinc mine. Eventually, all the lead and zinc plants will be consolidated into four groups headquartered in Huludao, Liaoning Province, Zhuzhou, Hunan Province, Shaoguan, Guangdong Province, and Baiyin, Gansu Province. Chinese per capita zinc consumption, about 0.45 kilograms, is low compared with the world average of 1.2 kilograms (Mining Journal, 1996k) but has been projected to increase by about 6.6% per year for the next 4 years (Eldridge, 1996a). During the present 5-year plan covering the period from 1996 to 2000, smelting capacity is to increase by about 180,000 tons per year while mine output is to increase only marginally, necessitating large imports of zinc concentrates. In 1996, the capacity of the Zhuzhou smelter was increased by 100,000 tons to 250,000 tons per year (Eldridge, 1996b). An additional 80,000-ton increase in capacity is to come from small, locally controlled smelters.

Finland.—At the end of May, Outokumpu Oy began mining the recently discovered Mullikkoräme deposit, near the town of Pyhajarvai in central Finland. Proven reserves reportedly amount to 700,000 tons at a grade of 8% zinc with byproducts of lead and copper and small amounts of silver and gold. By the end of year, production reached a rate of 240,000 tons per year, enabling mining to continue for about 3 years. For processing, ore was transported 10 kilometers to the nearby Pyhasalmi concentrator (Metal Bulletin, 1996f).

Mining at the Pyhasalmi zinc-copper mine reached a depth of 1,050 meters. Outokumpu began a 2-year project to study potential extension of mining to a 1,400-meter depth. The mine's reserves reportedly are sufficient to maintain the 1-million-ton-per-year production rate until the year 2000 (Mining Journal, 1996h).

Outokumpu has decided to invest $112 million to increase the capacity of its Kokkola smelter, to ensure that the smelter will remain competitive. By using a new method of direct leaching of zinc concentrate, developed by Outokumpu, the Finnish smelter is expected to increase capacity from 170,000 to 225,000 tons per year by the end of 1998 (Fineberg, 1996c).

Iran.—Iran ranks 10th in the world in zinc resources but produced only small amounts of zinc metal in 1996. To increase zinc production, a new 30,000-ton-per-year smelter in Bafgh, 580 kilometers southeast of Teheran, is to be commissioned at the beginning of 1997. The Iranian Government's planned $300 million investment in zinc metal production also includes a 7,000-ton-capacity smelter in the northwestern city of Zanjan, a 7,000-ton-capacity smelter in Bandar Abbas on the Persian Gulf, and three smaller units. By 2000, total annual capacity is expected to reach 50,000 tons of zinc metal. The required feed was to come from increased production at existing mines and a possible new mine in Mehdiabad in Yazd Province (Metal Bulletin, 1996g).

Ireland.—The Galmoy Mine in County Kilkenny is the first base-metal mine opened in Ireland in nearly 20 years. It was developed by Arcon Mines, a wholly owned subsidiary of Arcon International Resources. Resources of 6.2 million tons grading 11.4% zinc and 1.1% lead with low iron content and a trace of cadmium, reportedly have been identified. Production began at the end of 1996 and is expected to reach 650,000 tons of ore per year, yielding 120,000 tons of zinc concentrate by 1997. All the production has been presold to several European smelters (Mining Journal, 1996j).

In January 1996, Ireland's Ivernia West Plc., together with Minorco SA, proceeded with development of the Lisheen project. The ore body was found by Ivernia in 1980, and in 1994, Minorco bought a 50% interest in the project. The zinc-lead mine is expected to be one of the 10 largest mines in the world, producing an estimated 320,000 tons of zinc concentrates and 60,000 tons of lead concentrates per year for about 13.5 years (Metal Bulletin, 1996h). Production is scheduled to begin in 1998, and when fully operational, the mine is expected to provide employment for as many as 350 people.

Italy.—The state-owned resources group, Enirisorse SpA, began the process of privatizing its zinc smelter in Porto Vesme, Sardinia, and its refinery in Crotone, Calabria, southern Italy. The Porto Vesme zinc smelter produces about 70,000 tons of zinc slab per year using the Imperial Smelting Process. The Crotone electrolytic refinery, originally owned by Ente Nazionale Idrocarburi, produces about 100,000 tons of refined zinc plus other products, such as cadmium, indium, and germanium. Only about one-fourth of the required feed is sourced from the Iglesias area of Sardinia: the remainder is imported (Metal Bulletin, 1996e).

Japan.—Zinc production declined by more than 10%, owing mainly to the closure in June of Mitsubishi Materials Corp.'s

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Barajima smelter near Akita in northwestern Tahaku. Commissioned in 1953, its capacity had risen from the initial 6,720 to 105,000 tons per year by 1996. Proximity to the port and its reliance on imported concentrate was at first beneficial because the value of the yen was low. When the value of the yen began to rise, it was more economical, given the high cost of production, to import metal than to make it. During its last months, production was running at 80% of capacity, and the smelter was losing about $9.3 million per month (McCulloch, 1996). Although primary zinc production stopped, the Akita plant's alloy production facility will continue production at a rate of about 1,500 tons per month.

Kazakstan.—In November, the Government of Kazakstan announced plans to combine the Ust-Kamenogorsk base metal smelter, Leninogorsk and Ziryanovsk mining and processing enterprises, and the Irtysh copper smelter into a new company named AO (Aktsionernoye Obshchestvo) Kaztsink. All the enterprises are located within a 300-kilometer radius and are connected by rail. The Ust-Kamenogorsk base metals smelter reportedly has the capacity to produce 145,900 tons of lead, 215,000 tons of zinc, 37,100 tons of blister copper, and 6,600 tons of cathode copper per year. The Leninogorsk base metals mining and smelting enterprise reportedly has a mining capacity of 3.9 million tons of polymetallic ore per year, and its smelter has the capacity to produce 106,500 tons of zinc per year. The Zyryanovsk mining enterprise reportedly has the capacity to mine 6.4 million tons of polymetallic ore per year, and to process 5.2 million tons of ore per year, and is capable of producing copper, lead, and zinc concentrates. The newly formed Kaztsink would also have mining rights in the Maleyevsk, the Ridder-Sokol, and the Tishinsk mineral fields. The combined smelter production capacity would be 321,500 tons of zinc metal per year, far above the ability of domestic mines to supply concentrate. Only about one-half Kazakstan's refined zinc production was from domestic feed. Because of the lack of a domestic source of concentrate and the resulting under utilization of capacity, one of Ust-Kamenogorsk's three plants was closed for the entire year, and closure of additional plants is expected. If all smelters of the new AO Kaztsink were to remain in operation, then an investment of $270 million would be needed for modernization and repairs and for repaying a combined debt of $173 million (Mining Journal, 1996b). The future of the smelters will depend on the availability of concentrate, both domestic and imported.

In addition to AO Kaztsink, the small Tekeli lead and zinc mining and beneficiation complex in the Taldy-Kurgan region in the eastern part of the country consists of three mines and two beneficiation plants. The concentrates are sent to the Chimkent zinc smelter in southern Kazakstan, as well as to the Ust-Kamenogorsk smelter.

Peru.—Peru's zinc concentrate production increased by 68,313 tons, to 760,563 tons, a 9.9% increase over that of 1995. Empresa Minera del Centro del Peru S.A. (Centromin) posted the largest net increase, 16,000 tons of zinc in concentrate (U.S. Embassy, Lima, Peru, 1997). This 9.1% increase was achieved in spite of disruptions caused by continued privatization efforts and the resulting uncertain future. The strategy for privatization of Centromin was modified following the unsuccessful attempt to sell it as a single entity in 1994. The following year, the newly created Privatization Committee broke up the state mining enterprise into small independent units and decided to sell each unit individually. In September 1996, the Yauliyacu (formerly known as Casapalca) mining-smelting complex near Lima was offered for privatization. A month later, the Antamina copper-zinc deposit and the Quicay and the Paucaray gold properties were sold to Canadian companies. The Yauliyacu complex consists of a smelting plant, a 979,000-ton-capacity mill, and an underground polymetallic mine containing about 6.5 million tons of potential reserves of predominantly zinc ore (Fineberg, 1996b). The last unit offered for sale in 1996 was the Yauricocha polymetallic underground mine and mill, 350 kilometers southeast of Lima. It reportedly has reserves of 2.8 million tons and potential reserves of 6 million tons grading 5.3% zinc, 2.8% lead, 1.1% copper, 132 grams of silver, and 0.8 gram of gold per ton of ore. The daily mill capacity is about 1,500 tons, and the mine's typical annual production, expressed in contained metal in concentrate, is 18,000 tons of zinc, 7,000 tons of lead, 2,000 tons of copper, and 37 tons of silver. Because of lack of interest in Yauricocha, the Government initially decided to lower the asking price and eventually suspended the sale altogether. Sales of the Centromin components were to continue in the first quarter of 1997, when at least 51% of the shares of the 62-year-old La Oroya refinery complex was to be offered for sale (Metal Bulletin, 1996c).

Mining began in April at the Iscaycruz zinc-lead mine, operated by Empresa Minera Iscaycruz S.A. A 25-kilometer-long pipeline carries the concentrate from mine to the filter plant in Churin, outside of Lima. Production of zinc concentrate started in July and reached full annual capacity of 125,000 tons in December. Production for the year totaled 60,000 tons of zinc and 8,000 tons of lead in concentrate. The mine reportedly has proven and probable reserves of 2.7 million tons grading 21.4% zinc and 2.2% lead. Minera Iscaycruz is owned by Glencore International of Switzerland (45%), Corp. Minera Nor Peru S.A. (25%), Perubar S.A. (15), and Cia. de Minas Buenaventura S.A. (15%) (Mining Journal, 1996a).

According to Government estimates, by 2000, Peru will be producing 1 million tons of zinc in concentrate, up from 700,000 tons in 1996. The Cajamarquilla smelter, near Lima, is expected to play a significant part in that increase. A 20,000-ton-per-year expansion has been approved by Minero Peru, and a feasibility study to expand the capacity to 230,000 tons per year has been commissioned. Cajamarquilla is already one of the five most competitive smelters, and the expansion reportedly could make it the most efficient producer of refined zinc in the world. The net cost of converting concentrates to refined zinc at Cajamarquilla was 12.9 cents per pound. Cajamarquilla is owned by Cominco (82%), Marubeni Corp. (17%), and by employees (1%) (Metal Bulletin, 1996b).

Spain.—Boliden Mineral AB of Sweden, through its Spanish subsidiary Boliden Apirsa, plans to invest $100 million in the development of the Los Frailes deposit, near Seville. The zinc-

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lead-copper-silver deposit lies only 1 kilometer from the Aznalcóllar Mine, which closed at the end of 1996 owing to depletion of reserves. Average ore grade reportedly is 3.82% zinc, 2.17% lead, 0.35% copper, and 60 grams of silver per ton of ore (Hotter, 1996). The open pit mine and mill will have a production capacity of 110,000 tons of zinc, 45,000 tons of lead, 6,000 tons of copper, and 85 tons of silver per year. Because the Los Frailes Mine is so close to the old mine, the existing infrastructure is being used for processing.

In 1996, Ireland's Navan Resources purchased Minas de Almagrera S.A. from the Government-owned Sociedad Estatol de Participaciones Industriales for $3.43 million as part of Spain's privatization program. With the purchase, Navan acquired a metallurgical complex at Calanas that is capable of treating more than 1 million tons of polymetallic ore per year. Navan also acquired the Sotiel and the Migollas Mines. The Calanas complex will become fully operational with supplemental ore from Navan's Aguas Tenidas project, just 20 kilometers away, where a feasibility study was carried out for a possible production of 35,000 tons of zinc and 10,000 tons of lead concentrate. Reserves at Aguas Tenidas reportedly total 13.4 million tons of ore grading 5.7% zinc, 1.7% lead, 1.3% copper, 38 grams of silver, and 3 grams of gold per ton of ore. Almagrera's reserves at the time of sale included the 50-million-ton reserve at Sotiel reportedly grading 3.8% zinc, 1.6% lead, and 0.6% copper and the 6.4-million-ton Migollas deposit grading 3.84% zinc, 1.63% lead, and 0.62% copper (Metal Bulletin, 1996j).

Tunisia.—Following an evaluation of the capital investment required to lower the production cost, Société Minière de Bougrine S.A. suspended the operation of its Bougrine zinc-lead mine in Tunisia in October. According to the company officials, the added expenditure was not justified in light of current prices. The mine, in which Canada's Inmet Mining Corp. has a 48% interest, began operation in 1994. The 1996 production was expected to be 50,000 tons of zinc in concentrate and 8,500 tons of lead in concentrate, up from 38,000 and 6,300 tons, respectively, in 1995 (Metal Bulletin, 1996a).

Exploration.—World exploration expenditure by international mining companies for metals and minerals continued to grow for the third consecutive year. The composite annual expenditure of companies with at least a $3 million allotment for exploration, grew to about $3.5 billion, compared with only $2.7 billion in 1995. Also, the number of companies active in exploration increased from 154 to 223 in 1996, of which 112 were active in base metals exploration. If smaller companies were added to the total, then the estimated worldwide exploration expenditure for nonferrous metals would amount to $4.6 billion. Most of the exploration was conducted in Latin America, followed by Australia and Canada. Zinc deposit discoveries in Latin America include the Bogara deposit at the Florida Canyon area, Peru, the Aripuana project in northern Mato Grosso State, western Brazil, the Campo Morado deposit in Guerrero State, Mexico, and the San Fernando area, central Cuba. In Australia, Pasminco entered into a joint venture with Coolgardie Gold to explore a 500-square-kilometer area 150 kilometers north of Mount Isa, Queensland, where preliminary exploration drilling uncovered zinc mineralization ranging between 8.2% and 10.2% zinc. In a joint venture with Finland's Outokumpu, SIPA Resources of Australia discovered a 6.2-million-ton deposit at Sulphur Springs, Western Australia, at an average grade of 8.54% zinc and a small amount of copper. In Canada, the exploration by the joint venture of Westmin Resources Ltd. (60%) and Atna Resources Ltd. (40%) resulted in the discovery of a 5.3-million-ton deposit grading 13% zinc, 1.5% lead, 1.41% copper, 359 grams of silver, and 1.8 grams of gold per ton in the Wolverine area in the Yukon-Tanana Terrane in southwestern Yukon Territory (Northern Miner, 1996b). In June, Anvil Range Mining Corp. began a $6 million exploration in the vicinity of its Faro Mine. Inmet Mining Corp. reportedly will be able to continue operating its Winston Lake Mine for another 7 years because of the discovery of an additional 1.3-million-ton reserve grading 15.5% zinc and 0.9% copper. Additional exploration in Canada was conducted by Diadem Resources at the Pekan River area in Quebec and by Fortune Minerals in the Mazenod Lake area of the Northwest Territories, where grab samples reportedly showed metal concentrations up to 7.36% zinc, 3.8% lead, 1.4% copper, and 11.6 grams of silver per ton of ore (Whyte, 1996).

Outlook

The closure of several zinc mines at yearend may further aggravate the already short supply of concentrates anticipated for 1997. As new mines come on-stream, this shortage should gradually disappear. By 2000, the world mine production is forecast to increase by almost 1.4 million tons, about one-third of which is to come from Australia. This additional production should come from new mines at Century, Cannington, and Blendecale and, to a lesser extent, from expanded production of the existing Elura and Roseberry Mines. Australia's share of world production should increase from 18% in 1995 to 29% by 2000. This increased mine production may create an excess of concentrates into the next century, because expansion of smelter capacity will likely lag behind concentrate production. By the end of 1996, only one new smelter had been approved—the 170,000-ton smelter in Townsville, Australia. Production at this Korea Zinc-built smelter should start in October 1999. If needed, the best chance for additional smelting capacity could come from expansion of the existing smelters and the proposed 220,000-ton Gencor smelter in South Africa. Even if all these capacities should be brought on-stream, it would not affect the zinc market until about the year of 2000. In the meantime, increased consumption and constant metal production will further reduce the world stockpile and put upward pressure on the zinc price. It is anticipated that the total reported stocks of zinc could drop, from a peak level of 1.64 million tons in 1994, to 450,000 tons by the end of 1998.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT ZINC STATISTICS 1/

(Metric tons unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Production:						
Domestic ores, contained zinc		552,000	513,000	598,000	644,000	628,000
Domestic ores, recoverable zinc		523,000	488,000	570,000	614,000	600,000
Value, recoverable zinc	thousands	$674,000	$497,000	$619,000	$756,000	$615,000
Refined zinc:						
From domestic ores		227,000	214,000	201,000	223,000	214,000
From foreign ores		44,800	26,000	15,600	8,840	11,400
From scrap		128,000	141,000	139,000	131,000	140,000
Total		399,000	382,000	356,000	363,000	366,000
Secondary zinc 2/		238,000	217,000	222,000	222,000	238,000
Rolled zinc		48,200	W	W	W	W
Exports:						
Ores and concentrates (zinc content)		307,000	311,000	389,000	424,000	425,000
Slab zinc		565	1,410	6,310	3,080	1,970
Rolled zinc		5,430	6,600	6,680	5,180	5,020
Imports for consumption:						
Ores and concentrates (zinc content)		44,500	33,100	27,400	10,300	15,100
Refined (Slab) zinc		644,000	724,000	793,000	856,000	827,000
Rolled zinc		171	135	475	332	16,900
Stocks of slab zinc, Dec. 31:						
Producer		7,960	4,970	5,210	7,120	11,100
Consumer		57,900	61,600	64,600	64,400	58,400
Merchant		15,600	10,500	9,930	6,440	4,800
Total		81,500	77,000	79,700	78,000 r/	74,300
Government stockpile		341,000	326,000	286,000	272,000	257,000
Consumption:						
Refined zinc:						
Reported		814,000	828,000	843,000	917,000 r/	788,000
Apparent 3/		1,050,000	1,120,000	1,180,000	1,230,000 r/	1,210,000
All classes 4/		1,290,000	1,340,000	1,400,000	1,460,000	1,450,000
Price: Special High Grade, cents per pound		58.38	46.15	49.26	55.83	51.11
World:						
Production:						
Mine	thousand metric tons	7,250 r/	6,910 r/	7,000 r/	7,240 r/	7,440
Smelter	do.	7,260 r/	7,460 r/	7,450 r/	7,550 r/	7,530
Price: London Metal Exchange, cents per pound		56.24	43.64	45.26	46.82	46.50

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits, except prices; may not add to totals shown.

2/ Zinc in metal products and compounds derived directly from scrap; refined secondary zinc is listed separately in the table.

3/ Domestic production plus net imports, plus or minus stock changes.

4/ Apparent consumption of refined zinc plus reported consumption of zinc in metal products and compounds derived directly from ore, concentrate, or scrap.

TABLE 2
MINE PRODUCTION OF RECOVERABLE ZINC IN THE UNITED STATES, BY STATE 1/

(Metric tons)

State	1995	1996
Alaska	321,000	331,000 2/
Montana	22,700	19,400
Other	270,000	249,000
Total 3/	614,000	600,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Data in part based on publicly available information.

3/ Includes production from Colorado, Idaho, Illinois, Missouri, New York, and Tennessee.

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TABLE 3
LEADING ZINC PRODUCING MINES IN THE UNITED STATES IN 1996, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of zinc
1	Red Dog	Northwest Arctic, AK	Cominco Alaska Inc.	Zinc ore.
2	Elmwood-Gordonsville	Smith, TN	Savage Zinc Inc.	Do.
3	Balmat	St. Lawrence, NY	Zinc Corporation of America	Do.
4	Young	Jefferson, TN	ASARCO Incorporated	Do.
5	Pierrepont	St. Lawrence, NY	Zinc Corporation of America	Do.
6	Montana Tunnels	Jefferson, MT	Montana Tunnels Mining Inc.	Do.
7	Casteel 1/	Iron, MO	The Doe Run Co.	Lead ore.
8	Buick	do.	do.	Do.
9	Cumberland	Smith, TN	Savage Zinc Inc.	Zinc ore.
10	Clinch Valley	Grainger, TN	do.	Do.
11	Immel	Knox, TN	ASARCO Incorporated	Do.
12	Greens Creek	Southeastern, AK	Kennecott Mining Co.	Do.
13	Jefferson City	Jefferson, TN	Savage Zinc Inc.	Do.
14	Coy	do.	ASARCO Incorporated	Do.
15	New Market	do.	do.	Do.
16	Leadville Unit	Lake, CO	do.	Do.
17	Sweetwater	Reynolds, MO	do.	Lead-zinc ore.
18	West Fork	do.	do.	Do.
19	Fletcher	do.	The Doe Run Co.	Do.
20	Viburnum No. 29	Washington, MO	do.	Do.
21	Lucky Friday	Shoshone, ID	Hecla Mining Co.	Do.
22	Viburnum No. 28	Iron, MO	The Doe Run Co.	Do.
23	Rosiclare	Hardin and Pope, IL	Ozark-Mahoning Co.	Fluorspar.

1/ Includes Brushy Creek Mill.

TABLE 4
REFINED ZINC PRODUCED IN THE UNITED STATES 1/

(Metric tons)

	1995	1996
Primary:		
From domestic ores	223,000	214,000
From foreign ores	8,840	11,400
Total	232,000	226,000
Secondary	131,000	140,000
Grand total (excludes zinc recovered by remelting)	363,000	366,000

1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 5
REFINED ZINC PRODUCED IN THE UNITED STATES, BY GRADE 1/

(Metric tons)

Grade	1995	1996
Special High	117,000	111,000
Continuous Galvanizing	77,500	88,500
Other 2/	168,000	167,000
Total	363,000	366,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes High, Controlled Lead, and Prime Western grades.

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TABLE 6
SLAB ZINC CAPACITY OF PRIMARY ZINC PLANTS IN THE UNITED STATES, BY TYPE OF PLANT AND COMPANY

(Metric tons)

Type of plant and company	Slab zinc capacity 1995	1996
Electrolytic:		
Big River Zinc Corp., Sauget, IL	82,000	82,000
Savage Zinc, Inc., Clarksville, TN	100,000 r/	100,000
Electrothermic:		
Zinc Corp. of America, Monaca, PA 1/	146,000	146,000
Total operating capacity	328,000 r/	328,000

r/ Revised.
1/ Includes secondary capacity.

TABLE 7
STOCKS AND CONSUMPTION OF NEW AND OLD ZINC SCRAP IN THE UNITED STATES IN 1996, BY TYPE OF SCRAP 1/

(Metric tons, zinc content)

Type of scrap	Stocks, Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
Diecastings	W	3,380	--	3,320	3,320	W
Flue dust	W	5,070	4,040	4,040	8,080	W
Galvanizer's dross	W	22,500	24,200	--	24,200	W
Old zinc 2/	22	W	--	W	W	W
Remelt die-cast slab	W	3,030	--	3,050	3,050	W
Remelt zinc 3/	20	W	W	--	W	24
Skimmings and ashes 4/	6,460	26,000	28,400	--	28,400	4,050
Other 5/	8,900	137,000	55,600	80,800	136,000	4,430
Total	15,400	197,000	112,000	91,200	203,000	8,500

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes engraver's plates and rod and die scrap.
3/ Includes new clippings.
4/ Includes sal skimmings and die-cast skimmings.
5/ Includes chemical residues and solutions, electrogalvanizing anodes, fragmentized diecastings, and steelmaking dust.

TABLE 8
PRODUCTION OF ZINC PRODUCTS FROM ZINC-BASE SCRAP IN THE UNITED STATES 1/

(Metric tons)

Products	1995	1996
Redistilled slab zinc	131,000	140,000
Other zinc metal products 2/	6,470	4,450
Zinc in chemical products	61,500	82,500
Zinc dust	21,800	26,700

1/ Data are rounded to three significant digits.
2/ Includes electrogalvanizing anodes, remelt die-cast slab, and other metal alloys.

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TABLE 9
ZINC RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF SCRAP AND FORM OF RECOVERY 1/

(Metric tons)

	1995	1996
Type of scrap:		
New scrap:		
Zinc-base	96,700	110,000
Copper-base	146,000 r/	155,000
Magnesium-base	148 r/	331
Total	242,000 r/	265,000
Old scrap:		
Zinc-base	85,700	88,100
Copper-base	24,400 r/	24,700
Aluminum-base	711	819
Magnesium-base	178 r/	186
Total	111,000 r/	114,000
Grand total	353,000	379,000
Form of recovery:		
Metal:		
Slab zinc	131,000	140,000
Zinc dust	21,800	26,700
Other 2/	W	W
Total	155,000	167,000
In zinc-base alloys	W	--
In brass and bronze	134,000	127,000
In other metal alloys	W	W
In chemical products:		
Zinc oxide (lead free)	33,600	47,100
Zinc sulfate	19,600	27,300
Zinc chloride	W	2,730
Miscellaneous	10,700	7,660
Total	198,000	211,000
Grand total	353,000	379,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Includes electrogalvanizing anodes and zinc content of slab made from remelt die-cast slab.

TABLE 10
U.S. CONSUMPTION OF ZINC 1/

(Metric tons)

	1995	1996
Refined zinc, apparent	1,230,000 r/	1,210,000
Ores and concentrates (zinc content)	1,650	1,670
Secondary (zinc content) 2/	222,000	238,000
Total	1,460,000	1,450,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes secondary slab zinc and remelt zinc.

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TABLE 11
U.S. REPORTED CONSUMPTION OF ZINC IN 1996, BY INDUSTRY USE AND GRADE 1/

(Metric tons)

Industry use	Special High Grade	High Grade	Prime Western	Remelt and other grades	Total
Galvanizing	98,000	89,600	157,000	53,800	398,000
Zinc-base alloys	141,000	W	--	W	142,000
Brass and bronze	W	W	W	W	87,400
Other	146,000	21,500	80,400	254	161,000
Total	385,000	111,000	238,000	54,000	788,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 12
ZINC CONTAINED IN PIGMENTS AND COMPOUNDS 1/ PRODUCED AND SHIPPED IN THE UNITED STATES 2/

(Metric tons)

	1995		1996	
	Production	Shipments	Production	Shipments
Zinc chloride	W	W	2,730	2,770
Zinc oxide	104,000	104,000	125,000	128,000
Zinc sulfate	22,300	20,000	30,000	31,900

W Withheld to avoid disclosing company proprietary data.
1/ Excludes leaded zinc oxide and lithopone.
2/ Data are rounded to three significant digits.

TABLE 13
REPORTED SHIPMENTS OF ZINC CONTAINED IN ZINC OXIDE, BY INDUSTRY 1/ 2/

(Metric tons)

	1995	1996
Ceramics	2,710	4,950
Chemicals	24,000	26,200
Paints	3,840	5,430
Rubber	68,200	86,400
Other 3/	5,330	5,010
Total	104,000	128,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ In addition, zinc contained in zinc oxide was imported as follows: 1995-39,300 (revised) and 1996-45,000; distribution cannot be distinguished by industry.
3/ Includes agriculture and photocopying.

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TABLE 14
U.S. EXPORTS OF ZINC ORES AND CONCENTRATES, BY COUNTRY 1/

	1995		1996	
	Quantity (metric tons, zinc content)	Value (thousands)	Quantity (metric tons, zinc content)	Value (thousands)
Belgium	55,000	$27,300	61,100	$40,000
Canada	176,000	89,200	178,000	64,900
China	9,240	4,420	9,140	4,380
Germany	30,200	14,400	--	--
Japan	68,000	29,600	47,300	20,000
Korea, Republic of	22,300	10,700	46,100	22,000
Netherlands	25,400	12,300	60,200	28,800
Russia	6,870	2,300	--	--
Spain	15,400	3,330	19,800	5,630
Thailand	9,240	4,420	--	--
Other	6,320	2,940	3,440	4,020
Total	424,000	201,000	425,000	190,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 15
U.S. EXPORTS OF ZINC COMPOUNDS 1/

	1995		1996	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Lithopone	342	$570	319	$2,040
Zinc chloride	1,690	1,250	1,470	1,230
Zinc compounds, n.s.p.f.	1,690	4,350	1,250	4,670
Zinc oxide	7,090	9,110	5,770	9,430
Zinc sulfate	4,210	2,260	5,230	2,970
Zinc sulfide	377	498	112	1,410

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF ZINC COMPOUNDS 1/

	1995		1996	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Lithopone	1,450	$1,560	1,080	$1,030
Zinc chloride	2,450	2,370	2,420	2,140
Zinc compounds, n.s.p.f.	136	314	1,190	1,280
Zinc oxide	49,100	54,200	56,300	57,500
Zinc sulfate	5,400	3,820	4,050	2,840
Zinc sulfide	--	--	517	4,240

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

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TABLE 17
ZINC: WORLD MINE PRODUCTION (CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria	4,044	3,672	3,050	3,700 r/	3,700 3/
Argentina	40,978	31,395	26,933 r/	32,104 r/	33,000
Australia	1,025,000	1,010,000	995,000	937,000 r/	1,071,000 3/
Austria	15,787	20,014	-- e/	-- e/	--
Bolivia	143,936	122,638	100,742	146,131	144,000
Bosnia and Herzegovina e/	2,000	350	300	300	300
Brazil	149,000	171,800	145,900	167,259 r/	170,000
Bulgaria	29,000	32,000	28,500 r/	25,600 r/	19,800
Burma	1,078	850	1,316	721 r/	590
Canada	1,324,675	1,007,257	984,000	1,121,172 r/	1,235,274 3/
Chile	29,730	29,435	31,038	33,000 r/	30,000
China e/	758,000	775,000	990,000	1,010,000 r/	1,010,000
Colombia	277	279	275	275 e/	275
Czech Republic 4/	XX	1,500 e/	100	--	--
Czechoslovakia e/ 5/	7,500	XX	XX	XX	XX
Ecuador e/	100	100	100	100	100
Finland	32,817	22,529	16,916 r/	11,200 r/	25,000
France	16,539	13,834	1,000 e/	-- e/	--
Georgia e/	2,000	1,500	1,000	700	500
Germany e/	14,288 3/	--	--	--	--
Greece	27,496 r/	28,812 r/	33,216	20,400 r/	20,000
Honduras	29,008	18,256	16,697	26,213 r/	25,325 3/
India	152,800	156,300	147,300	154,500 r/	148,200 3/
Iran	66,000	77,000	72,900 r/	145,100 r/	75,600 3/
Ireland	194,100	193,700	195,000 e/	184,118 r/	164,168 3/
Italy	35,032	7,100	22,900	23,100 r/	20,000
Japan	134,510	118,599	100,653	95,274	79,709 3/
Kazakstan e/	250,000	250,000	190,000	225,000 r/	225,000
Korea, North e/	200,000	210,000	210,000	210,000	210,000
Korea, Republic of	21,883	13,808	7,122	7,747 r/	8,384 3/
Macedonia e/	8,800 r/	8,800 r/	8,800 r/	8,800 r/	8,500
Mexico	294,408	369,697	381,689	363,658	377,599 3/
Morocco	22,604	62,874	74,693	79,947 r/	79,662 3/
Namibia	36,053	28,380	33,414	30,209	33,955 3/
Norway	21,058	14,327	15,586	9,972 r/	5,200
Peru	604,525	664,045	690,017	692,250 r/	760,563 3/
Poland	151,700	150,900	151,000 r/	154,500 r/	155,000
Romania	25,813	28,017	35,357	36,737 r/	30,945 3/
Russia e/	160,000 r/	150,000 r/	145,000 r/	130,000 r/	135,000
Saudi Arabia e/	-- r/	-- r/	-- r/	-- r/	--
Serbia and Montenegro	19,718	9,704	1,609 r/	3,195 r/	4,000
Slovakia e/ 4/	XX	1,000	1,000	1,000	1,000
Slovenia	1,550	--	-- e/	--	--
South Africa	71,928	77,096	76,361	73,656 r/	76,853 3/
Spain	204,655	169,892 r/	150,425	172,469 r/	170,000
Sweden	171,539	168,617	159,858	160,000 e/	160,000
Thailand e/	62,000	70,000	56,000	20,000	30,000
Tunisia	4,090	2,400	14,548 r/	44,244 r/	31,920 3/
Turkey 6/	32,514	32,500 e/	34,000	7,538 r/	9,118 3/
United States	552,000	513,000	598,000	644,000	628,000 3/
Uzebekistan e/	50,000 r/	35,000 r/	30,000 r/	15,000 r/	12,000
Vietnam e/	15,000	15,000	15,000	15,000	15,000
Zaire e/	22,300 3/	6,500	1,000 r/	-- r/	--
Zambia 7/	14,706	16,704	--	--	--
Total	7,250,000 r/	6,910,000 r/	7,000,000 r/	7,240,000 r/	7,440,000

See footnotes at end of table.

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TABLE 17--Continued
ZINC: WORLD MINE PRODUCTION (CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY 1/ 2/

e/ Estimated. r/ Revised. XX Not applicable.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through July 1, 1997.
3/ Reported figure.
4/ Formerly part of Czechoslovakia; data were not reported separately until 1993.
5/ Dissolved Dec. 31, 1992.
6/ Content in ore hoisted.
7/ Data are for years beginning Apr. 1 of that stated. Content of ore milled. Mine closed June 1994.

TABLE 18
ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Algeria, primary	25,000	29,000	24,000	24,300 r/	24,000
Argentina:					
Primary	34,500	31,000 r/	30,000 r/	31,000 r/	31,000
Secondary e/	2,800	2,800	1,000 r/ 3/	2,000 r/	2,000
Total	37,300	33,800 r/	31,000 r/	33,000 r/	33,000
Australia:					
Primary 4/	328,000 r/	316,000	323,000	320,000 r/	326,000 3/
Secondary e/	4,500	4,500	4,975 r/ 3/	4,500	4,500
Total e/	333,000 r/	321,000	327,975 r/ 3/	324,500 r/	331,000
Austria, primary and secondary	5,537	6,838	--	--	--
Belgium, primary and secondary	310,600	299,600	306,200	301,100 r/	297,400 3/
Brazil:					
Primary	180,414	183,393 r/	187,304 r/	188,033 r/	188,000
Secondary	7,000	7,200	7,000 e/	7,000 e/	7,000
Total	187,414	190,593 r/	194,000 r/ e/	195,000 r/ e/	195,000
Bulgaria, primary and secondary	57,820	54,039	79,500 r/	79,700 r/	80,800
Canada, primary	671,702	659,881	690,965	720,346 r/	715,553 3/
China, primary and secondary e/	719,000	857,000	1,010,000	1,080,000 r/	1,120,000
Czechoslovakia, secondary 5/	1,100	XX	XX	XX	XX
Finland, primary	170,523	170,934	173,000 e/	176,600 r/	175,000
France, primary and secondary	318,700	309,800	308,600 r/	290,000 r/ e/	320,000
Germany, primary and secondary	383,117	380,948	359,878	322,500 r/	327,000
Hungary, secondary e/	1,000	1,000	--	--	--
India:					
Primary	128,100	141,700	156,400	146,500	143,600 3/
Secondary e/	200	200	500	500	500
Total e/	128,000	142,000	157,000	147,000	144,000
Italy, primary and secondary	252,600	254,000 e/	255,900 r/	267,600 r/	260,000
Japan:					
Primary	645,000	609,300	571,900	573,900	500,700 3/
Secondary	135,600	135,200	141,400	143,000	141,500 3/
Total	780,600	744,500	713,300	716,900	642,200 3/
Kazakstan, primary	260,000 e/	260,000 e/	190,000 r/	168,300 r/	168,500 3/
Korea, North, primary e/	175,000	200,000	200,000	200,000	200,000
Korea, Republic of, primary	253,000	272,000 e/	271,110 r/	279,335 r/	286,526 3/
Macedonia, primary and secondar	30,000	30,000	30,000	30,000	30,000
Mexico, primary	151,600	209,900	209,200	222,748	221,736 3/
Netherlands, primary 6/	218,410	206,700	212,600	206,300 r/	212,400 3/
Norway, primary	127,564	129,192	131,921	121,576 r/	126,000
Peru, primary	124,000 r/	157,000 r/	182,000 r/	158,987 r/	173,138 3/
Poland, primary and secondary	134,600	149,000	156,000 r/	166,000 r/	165,000
Portugal, primary e/	2,200	3,500 r/	4,200 r/	4,200 r/	4,800
Romania, primary and secondary	11,600	14,100	18,500	14,000 r/	14,000
Russia: e/					
Primary	185,000 r/	200,000 r/	137,800 r/ 3/	167,000 r/	170,000
Secondary	60,000	60,000	50,000	50,000	50,000
Total	245,000 r/	260,000 r/	188,000 r/	217,000 r/	220,000

See footnotes at end of table.

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TABLE 18--Continued
ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Serbia and Montengero, primary and secondary	14,182	6,985	3,895	5,976 r/	6,000
Slovakia, secondary e/ 7/	XX	1,000	1,000	1,000	1,000
Slovenia, primary and secondary e	2,500	2,500	2,500	2,500	2,000
South Africa, primary	83,200	96,154	93,850	98,782	99,000
Spain, primary and secondary	351,900	341,600 r/	294,700 r/	358,000 r/	350,000
Thailand, primary	60,557	65,000 e/	58,513	46,398	50,000
Turkey, primary	18,770	18,500	18,567	17,050 r/	25,000
Ukraine, secondary e/	15,000	15,000	15,000	5,000	2,000
United Kingdom, primary and secondary	96,813	102,391	101,300	105,998 r/	96,867 3/
United States:					
Primary	272,000	240,000	217,000	232,000	226,000 3/
Secondary	128,000	141,000 r/	139,000	131,000	140,000 3/
Total	399,000	382,000	356,000	363,000	366,000 3/
Uzbekistan, primary e/	65,000	65,000	70,000	70,000	40,000
Vietnam, primary and secondary e	10,000	10,000	10,000	10,000	10,000
Zaire, primary e/	18,800 3/	4,150 r/	1,000	--	--
Zambia, primary 8/	7,288	3,446	--	--	--
Grand total	7,260,000 r/	7,460,000 r/	7,450,000 r/	7,550,000 r/	7,530,000
Of which:					
Primary	4,210,000 r/	4,270,000 r/	4,150,000 r/	4,170,000 r/	4,110,000
Secondary	355,000	368,000	360,000 r/	344,000 r/	349,000
Undifferentiated	2,700,000	2,820,000 r/	2,940,000 r/	3,030,000 r/	3,080,000

e/ Estimated. r/ Revised. XX Not applicable.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Wherever possible, detailed information on raw material source of output (primary--directly from ores, and secondary--from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 1, 1997.

3/ Reported figure.

4/ Excludes zinc dust.

5/ Dissolved Dec. 31, 1992. All production in Czechoslovakia in 1992 came from Slovakia.

6/ Sales.

7/ Formerly part of Czechoslovakia; data were not reported separately until 1993.

8/ Data are for years beginning Apr. 1 of that stated. Imperial smelter production ceased in Mar. 1993. Electrolytic production was suspended Jan. 1991 to Mar. 1993 and ceased in Jan. 1994.

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ZIRCONIUM AND HAFNIUM

By Joseph Gambogi

Zirconium and hafnium are relatively abundant in the Earth's crust; however, zircon is the primary naturally occurring mineral of commercial significance. Baddeleyite, a natural form of zirconia (ZrO_2), has some minor commercial significance. Zirconium and hafnium are both contained in zircon at a ratio of about 50:1. Zircon is a byproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. The major end uses of zircon are refractories, foundry sands (including investment casting), and ceramic opacification.

World production of zirconium mineral concentrates was estimated to have decreased 4% in 1996. U.S. production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of milled zircon decreased slightly in 1996. According to U.S. Customs trade statistics, the United States was a net importer of zirconium ore and concentrates. However, during 1996 the United Sates was less import reliant than in 1995. Imports of zirconium ore and concentrates increased slightly while exports increased 13%.

With the exception of prices, all data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers.

Production

Data for zirconium and hafnium materials are developed by the U.S. Geological Survey from one voluntary survey of domestic operations. Of the 33 operations surveyed, 23 responded, representing 70% of the domestic production data in table 1. Data for nonrespondents were estimated based on prior year levels. Domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Milled zircon production was nearly unchanged compared with that of 1995, while zirconium oxide production increased 6%. *(See table 1.)*

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands for the titanium minerals rutile and ilmenite. U.S. mine producers of zircon in 1996 were RGC (USA) Mineral Sands, Inc. and E.I. du Pont de Nemours and Co. (DuPont). Both producers mined heavy-mineral sand deposits in Florida. U.S. producers of zirconium and hafnium metal were Wah Chang, Albany, OR, and Western Zirconium, Ogden, UT. Primary zirconium chemicals were produced by Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals were produced by about 10 companies, and zirconia was produced from zircon sand at plants in Alabama, New Hampshire, New York, Ohio, and Oregon.

In 1996, RGC began construction of production facilities at the Old Hickory deposit south of Richmond, VA. Initial production was expected to commence in 1997 with a mine life of approximately 17 years. When the mine is fully operational, RGC expects to produce up to 30,000 metric tons per year of zircon (Mineral Sands Report, 1997b).

Consumption

Approximately 95% of all zirconium consumed is in the form of zircon, zirconium oxide, or other zirconium chemicals. The remainder is consumed as zirconium metal and zirconium-containing alloys.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds. Zircon, in the form of refractory bricks and blocks, is used in furnaces and in hearths for containing molten metals. Glass tank furnaces use fused cast and bonded alumina-zirconia-silica-base refractories. Baddeleyite is used principally in the manufacture of alumina-zirconia abrasives, but also is used in ceramic colors and refractories.

Stabilized zirconium oxide exhibits high light reflectivity and good thermal stability and is primarily used as an opacifier and pigment in glazes and colors for pottery and other ceramic products. Yttria-stabilized zirconia is used in the manufacture of sensors that control combustion in furnaces and automobile engines.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium is used as cladding for nuclear fuel rods. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and is used in the chemical process industries because of its excellent corrosion resistance. Hafnium is used in nuclear control rods because of its high thermal neutron absorption cross section. However, the largest end use for hafnium metal is as an alloy addition in superalloys.

Prices

In 1996, a tight supply of zirconium-base concentrates caused prices to increase significantly compared with those of 1995. Domestic prices of standard-grade zircon increased 31% compared with those of 1995. Prices for imported grades of zircon experienced similar increases. Published prices for zirconium, hafnium, and zirconium oxide products were unchanged. *(See table 2.)*

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Foreign Trade

According to U.S. Customs trade statistics, the United States was a net importer of zirconium ore and concentrates in 1996. U.S. imports of zirconium ore and concentrates were 92,500 tons, nearly unchanged compared with those in 1995. Australia and South Africa supplied about 99% of the imports of ores and concentrates.

The United States was a net exporter of zirconium and hafnium metal in 1996. Imports of unwrought zirconium and waste and scrap metal were 619 tons, a 16% decrease compared with those of 1995. The leading import sources of zirconium were Canada and France. U.S. exports of zirconium metal and waste and scrap were 136 tons, a 17% decrease compared with those of 1995. U.S. imports of unwrought hafnium and waste and scrap were 8 tons, a 60% increase compared with those of 1995. *(See tables 3 and 4.)*

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 1996 is estimated to be 857,000 tons, a 4% decrease compared with that of 1995. Australia and South Africa supplied about 84% of all non-U.S. production. World reserves of zircon are estimated to be 32 million tons ZrO_2, while identified world resources of zircon exceed 60 million tons ZrO_2. During 1996, the zirconium industry was active in the exploration and development of mineral deposits on a global basis, particularly in Australia, Kenya, Mozambique, and South Africa. *(See table 5.)*

Australia.—Australia is the largest producer of zircon concentrates in the world. In 1996, major producers of zircon concentrates were RGC (USA) Mineral Sands Ltd., Westralian Sands Ltd., Tiwest Joint Venture, Cable Sands Ltd., and Consolidated Rutile Ltd. (CRL). Although industry estimates of production were nearly unchanged compared with those of 1995, official sources reported production of zircon concentrates decreased significantly in 1996 (Mineral Sands Report, 1997a).

At the end of 1996, BHP Titanium Minerals Pty. Ltd.'s Beenup project in Western Australia was close to being commissioned. At full capacity, the operation was expected to produce 20,000 tons per year of zircon as a byproduct of its ilmenite production. Shipments of heavy-mineral concentrates were scheduled to begin in 1997 (Broken Hill Proprietary Company, 1996.)

CRL relocated the dredge and floating concentrator from its exhausted Bayside deposit to its Ibis-Alpha heavy- mineral deposit on North Stradbroke Island. During the transition, the plant was upgraded to process up to 3,000 tons of sand per hour. According to the company, the operation has an expected life span of 9 years (Mining Journal, 1996). In 1996, RGC acquired controlling interest in Cudgen RZ Ltd. Through the acquisition, RGC now holds controlling interest in CRL (Industrial Minerals, 1996b).

India.— Cookson Group plc. announced that its joint venture with Johnson Matthey, Cookson Matthey Ceramics (CMC), was constructing a zircon-base opacifier facility near Bangalore. The new facility adds to the list of international CMC operations in Germany, Italy, Spain, the United Kingdom, and the United States, CMC plans to construct a similar facility in Malaysia. No details regarding capacity were released (Cookson Group plc., 1996).

Japan.—Tosoh Corp. increased its zirconia powder capacity from 270 to 370 tons per year. Zirconia powder is produced by Tosoh from zircon sand through a batch process of hydrolysis followed by calcining, milling, and spray drying. Increased demand for zirconia powder by the electronics industry was cited as the driving force for the expansion (Industrial Minerals, 1997).

Kenya.—In 1996, Tiomin Resources Inc. identified several mineral sands deposits and acquired an 80% interest in the licensed mineral rights for prospecting areas along the Kenyan coast. Pangea Goldfields Inc. retained 20% interest in the properties. According to Tiomin, a resource of 2 billion tons grading 3% heavy minerals has been defined by preliminary drilling and sampling. In 1996, Tiomin commenced a drilling program on the Mamburi, Sokoke, Kwale, Mombasa, and Sabaki deposit areas (Tiomin Resources Inc., 1996).

Mozambique.—Gencor Ltd. and Edlow Resources' joint venture TiGen completed a prefeasiblity study of a heavy-mineral deposit near Moebase. Exploration results indicated a resource in excess of 1,000 million tons containing 4% heavy minerals. The prefeasibility study concluded ilmenite from the deposit could be used to produce titanium slag suitable for use by chloride-route pigment operations (Gencor Ltd., 1996).

South Africa.—South Africa is the second largest source of zirconium minerals production in the world. Zirconium minerals are produced from three sources. Heavy-mineral mining operations of Richards Bay Minerals and Namakwa Sands Ltd. yield zircon concentrates while baddeleyite is produced at Palabora as a byproduct of open pit copper and phosphate mining.

The Palabora Mining Co. reported production of baddelyite concentrates in 1996 was 11,400 tons, a decrease of 14% compared with that of 1995. Palabora decided to proceed with plans to produce zirconium-based sulfate from zircon. Production is expected to commence in August 1997, with full production of 7,900 tons per year containing 38% ZrO_2 targeted for 1999 (Palabora Mining Company Ltd., 1996).

Iscor Ltd. was proceeding with plans to develop its heavy-mineral production at the Hilendale deposit near KwaZulu-Natal. When completed, capacity at the operation is expected to include 35,000 tons per year of zircon (Iscor Heavy Minerals, 1996).

Vietnam.—Bimal Minerals Co. completed construction and commenced production of heavy-minerals concentrate at its wet separation plant at Cat Khahn in Binh Dinh Province. Bimal is a joint venture between Binh Dinh Minerals Co., Malaysia Mining Co., and Pendorong Co. Bimal plans to truck the concentrate from the wet separation plant to its existing dry separation plant in Degi. Although titanium mineral production

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began in 1996, the zircon-bearing fraction from the separation plant was stockpiled for future upgrading (Industrial Minerals, 1996a).

Outlook

Global demand for zirconium materials is expected to increase by 3% annually over the next few years. A relatively tight supply of zircon resulted in increased prices of zirconium products in 1996. However, over the next few years, the supply and demand of zircon is expected to be in closer balance. Expansions in supply are expected in Mozambique, South Africa, and the United States, while further exploration and development efforts are likely in India, Kenya, Ukraine, and Vietnam.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS 1/

(Metric tons)

	1992	1993	1994	1995	1996
Zircon:					
Production:					
Concentrates	108,000	W	W	W	W
Milled zircon	45,100	46,700	53,300	56,000	55,300
Exports	27,900	35,900	32,000	40,300	35,000
Imports for consumption 2/	37,400	70,000	82,000	93,600	92,500
Consumption, apparent 2/	121,000	W	W	W	W
Stocks, Dec. 31: Dealers and consumers 3/	21,600	26,000	30,100	33,400 r/	33,700
Zirconium oxide:					
Production 4/	8,690	10,000	12,100	14,200	15,000
Exports 5/	NA	1,280	1,220	1,680	1,480
Imports for consumption 5/	NA	1,990	2,400	4,370	5,240
Consumption, apparent	NA	W	W	W	W
Stocks, Dec. 31: Producer 4/	719	W	W	W	W

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Includes insignificant amounts of baddeleyite.
3/ Excludes foundries.
4/ Excludes intermediate oxides associated with metal production.
5/ Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material	1995	1996
Zircon:		
Domestic, standard-grade, f.o.b. Starke, FL, bulk, per short ton 1/	$319.00	$419.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, FL, bulk, per short ton 1/	291.00	381.00
Domestic, premium-grade zircon, Starke, FL, bulk, per short ton 1/	354.00	489.00
Imported sand, ceramic application, f.o.b., bulk, per metric ton 2/	$290.00 - 360.00	$410.00 - 440.00
Imported sand, refractory application, f.o.b., bulk, per metric ton 2/	300.00 - 360.00	390.00 - 425.00
Imported sand, foundry sand application, f.o.b., bulk, per metric ton 2/	290.00 - 360.00	380.00 - 420.00
Baddeleyite, imported concentrate: 3/		
98% to 99% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.91 - .95	.91
Over 99% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	1.32 - 1.36	1.13
Zirconium oxide: 4/		
Powder, commercial-grade, drums, 2,000-pound minimum, per pound	3.00 - 6.60	3.00 - 6.60
Electronic, same basis, per pound	3.50 - 8.00	3.50 - 8.00
Insulating, stabilized, 325° F, same basis, per pound	3.35 - 4.00	3.35 - 4.00
Insulating, unstabilized, 325° F, same basis, per pound	3.35 - 4.00	3.35 - 4.00
Dense, stabilized, 300° F, same basis, per pound	3.60	3.60
Zirconium: 5/		
Powder, per pound	75.00 - 150.00	75.00 - 150.00
Sponge, per pound	9.00 - 12.00	9.00 - 12.00
Sheets, strip, bars, per pound	20.00 - 50.00	20.00 - 50.00
Hafnium: Sponge, per pound 5/	75.00 - 95.00	75.00 - 95.00

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TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY 1/

Class and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Ore and concentrates:				
Argentina	554	$217	234	$272
Belgium	365	198	672	390
Brazil	1,190	354	1,590	706
Canada	7,850	3,150	7,920	3,780
China	1,080	974	349	474
Colombia	2,510	1,910	1,800	2,050
Dominican Republic	234	236	255	303
Ecuador	153	106	127	147
France	791	451	1,090	836
Germany	8,790	3,450	8,420	4,320
Hong Kong	779	758	1,560	1,660
Indonesia	624	592	429	519
Ireland	--	--	114	134
Italy	956	298	166	114
Japan	659	267	268	102
Korea, Republic of	158	85	347	251
Malaysia	273	263	136	159
Mexico	8,770	2,800	5,110	2,420
Pakistan	371	313	20	15
Philippines	215	192	78	92
Singapore	78	92	215	272
Spain	201	99	276	269
Sweden	--	--	528	259
Taiwan	286	222	195	206
United Kingdom	1,770	1,500	1,330	1,040
Venezuela	1,380	1,260	1,480	1,650
Other	287	226	338	324
Total	40,300	20,000	35,000	22,800
Unwrought zirconium and waste and scrap:				
Japan	58	1,620	32	713
United Kingdom	24	627	41	1,250
Other	81 r/	2,270 r/	64	1,580
Total	164	4,520	136	3,550

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY 1/

Class and country	1995 Quantity (metric tons)	1995 Value (thousands)	1996 Quantity (metric tons)	1996 Value (thousands)
Zirconium ore and concentrates:				
Australia	52,900	$12,000	44,500	$15,000
South Africa	38,800	10,500	47,100	19,700
Other	1,860	2,960	943	1,530
Total	93,600	25,400	92,500	36,200
Zirconium, unwrought and waste and scrap:				
Canada	185 r/	1,190 r/	117	1,630
France	393 r/	31,200 r/	309	23,100
Germany	82 r/	10,800 r/	46	7,770
Japan	38 r/	725 r/	44	1,690
Netherlands	--	--	37	2,480
United Kingdom	15 r/	172 r/	28	161
Other	22 r/	588 r/	38	922
Total	735 r/	44,600 r/	619	37,800
Hafnium, unwrought and waste and scrap:				
Australia	--	--	(2/)	32
France	5	827	7	1,190
Germany	(2/)	186	1	311
Hong Kong	(2/)	113	--	--
United Kingdom	--	--	(2/)	46
Total	5	1,130	8	1,580

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1992	1993	1994	1995	1996 e/
Australia	355,000	414,000	502,000	505,000 r/	462,000 3/
Brazil 4/	16,874	13,252	17,064 r/	16,343 r/	16,500
China e/	15,000	15,000	15,000	15,000	15,000
India e/	18,000	17,000	18,000	18,000	19,000
Indonesia e/	2,500	2,500	2,500	2,000	2,000
Malaysia	2,608	2,184	1,656	3,790	3,600
Russia e/ 5/	3,000	2,500	2,500	2,500	2,500
Sierra Leone e/	1,329 3/	1,200 r/	1,300	--	--
South Africa e/ 6/	243,000	243,000	226,000	250,000	260,000
Sri Lanka	13,368	14,401	22,310	20,000 e/	21,000
Thailand	1,723	707	326	-- r/	--
Ukraine e/	75,000	70,000	65,000	60,000	55,000
United States	108,000	W	W	W	W
Total	856,000	796,000 r/	874,000	893,000 r/	857,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Includes data available through June 18, 1997.
3/ Reported figure.
4/ Includes production of baddeleyite-caldasite.
5/ Includes production of baddeleyite.
6/ Includes production of zircon and baddeleyite.

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